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Surviving in farmlands: causes of adult cheetah mortality in Botswana

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INTRODUCTION

Cheetahs (*Acinonyx jubatus*), currently classified as Vulnerable (A2acd) on the IUCN Red List, face many threats such as habitat transformation, human–wildlife conflict, a depleting prey base, illegal trade, climate change, fragmented populations, and diseases (Durant, Mitchell, Ipavec & Groom, 2015; Marker *et al.*, 2018). In Botswana, cheetahs are widespread at low densities and their current resident range is approximately 459 567 km² (79% of Botswana's total area) (Botswana National Predator Strategy, 2002; DWNP, 2018; IUCN SSC, 2015; Klein, 2007). The country hosts 24% of the global cheetah population, and 77% of this national cheetah population survives on communal and commercial farmlands outside formally protected areas (DWNP, 2018). Range-wide, there is a bias in the data on cheetah population demographics from protected areas (Durant *et al.*, 2017). This is because of difficulties associated with the accessibility of private lands, and bush encroachment caused by overgrazing. The bush encroachment impedes visual observations and the usage of tracking devices such as VHF and long-range (LoRa) networks (Durant *et al.*, 2017; Cheetah Conservation Botswana, pers. obs.).

In the wild, cheetahs can live up to 12–14 years, but on average they live 5–7 years (Caro, 1994; Durant, Kelly & Caro, 2004). Juvenile mortality among wild cheetahs is high compared to that of other felids, and death caused by other carni-

vores accounts for 89% of cheetah cub mortality (Laurenson, 1994). Adult mortality in protected areas is caused by interspecific and intraspecific competition, low hunting success and environmental factors such as rainfall, but on farmlands, mortality is predominantly caused by human persecution (Boast, 2014; Durant *et al.*, 2004; Marker, Dickman, Jeo, Mills & Macdonald, 2003a; Marker, Dickman, Mills & Macdonald, 2003b; Wachter *et al.*, 2011). On Namibian farmlands, male and female cheetahs have an 80% and 86% chance, respectively, of dying between the age of independence and six years (Marker *et al.*, 2003a), with an average lifespan of 4.6 years (Weise *et al.*, 2017). Natural causes of death on farmlands, especially of adults, remain largely unknown, although lethal encounters between males have been described (Melzheimer *et al.*, 2018). Adult cheetahs have high reproductive values (Crooks, Sanjayan & Doak, 1998; Weise *et al.*, 2017), therefore, changes in adult mortality are likely to strongly affect population growth (Crooks, Sanjayan & Doak, 1998), including population suppression after increased human persecution, but also potentially fast population rebounds if anthropogenic mortalities are prevented. Currently, population projections show that when cheetahs outside protected areas are further subject to high levels of threats in the future, the global cheetah population may decline by more than 50% over the next 15 years (approximately three cheetah generations) (Durant *et al.*, 2017). Botswana's cheetah population is connected to the cheetah populations of all neighbouring countries and therefore forms a critical part of the entire southern African population.

To determine the causes of death of cheetahs on Botswana's farmlands, we analysed a database with 20 years of mortality records of resident and translocated adult cheetah. Our analysis provides insight into cheetah mortality and can help guide long-term conservation strategies for cheetahs outside protected areas.

METHODS

We reviewed and analysed a database of 42 adult cheetahs (27 males and 15 females) that were collared in the southern and western farmlands of Botswana between 2003 and 2022. This arid scrub and savanna landscape is mostly used for livestock farming on communal, leasehold and freehold land (National Resource Services, 2002). Cheetahs were collared for various research

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projects on farmlands ($n = 31$) or to monitor movement after translocations to protected areas ($n = 11$, see Boast, Good & Klein, 2015, for more details). Cheetahs were caught using limited access cage traps and anaesthetized by a local veterinarian. Individuals were fitted with different brands of GPS and Iridium satellite tracking collars, including Vectronic Aerospace, Advanced Telemetry Systems (ATS), African Wildlife Tracking (AWT), and SirTrack Wildlife Tracking, with various settings. Collaring was conducted under all local guidelines, permits and ethics regulations according to the Department of Wildlife and National Parks of the Ministry of Environment and Tourism of the Government of Botswana under permit no. EWT 8/36/4XXXVIII (37-40). For each individual, health checks were performed to ensure that the cheetah was fit for collaring, with morphology measurements (as described in Boast, Houser, Good & Gusset, 2013) and blood samples taken from each individual. Cheetahs that were collared and released at the point of capture are herein referred to as cheetahs collared for 'research purposes' or 'resident cheetahs'. Cheetahs that were collared and translocated because of conflict with farmers are referred to as 'translocated cheetahs'. Translocated cheetahs had a hard release into a combination of land uses (protected areas, wildlife management areas and farmlands). Upon receiving mortality signals from the cheetah collar, researchers visited the site to retrieve the collar and investigate the cause of death. Photographs were taken, and a veterinarian was consulted if needed. Cheetahs were categorized as having died from unknown causes if no clear debilitating injuries were present, no bite

wounds were found and there were no signs of struggle.

RESULTS

We confirmed 23 deaths while collars were actively transmitting, accounting for 55% of the 42 total collared adult cheetahs. Although the confirmed cheetah deaths occurred between 18 (minimum) and 547 days (maximum) after collaring, 83% (19) died within 365 days of collaring. On average, cheetahs died 148 days after collaring, and 17% did not survive beyond one month. We recorded the deaths of six female (40% of females collared) and 17 male cheetahs (63% of males collared). All cheetahs were considered to be in good, healthy condition, with their estimated ages to be between two and eight years old. We detected six different causes of mortalities, but in 30% ($n = 7$) of the cases, the cause of death could not be identified (Table 1). The majority of mortalities (44%) were human-induced, although several natural causes of death were also reported, representing 26% of the cases. Furthermore, we detected 14 deaths of resident cheetahs on farmland (45% of all collared resident individuals) and nine deaths of translocated individuals (82% of all collared translocated individuals) (Table 1).

DISCUSSION

The most recorded causes of mortality were human persecution (shooting, snaring) and injuries. Human persecution was the main cause of mortality for resident farmland cheetahs, which was likely caused by human–wildlife conflict associated with livestock predation. In contrast, for the cheetahs that were translocated into protected

Table 1. Summary of causes of death in 23 collared adult cheetahs recorded by Cheetah Conservation Botswana between 2003 and 2023.

Cause of mortality	Total number of mortalities	Number of mortalities for translocated cheetahs ($n = 9$)	Number of mortalities for resident cheetahs ($n = 14$)	Percentage of total mortalities (%)
Total human-induced causes	10	2	8	44%
Persecution	9	1	8	
Poaching	1	1	–	
Total natural causes	6	3	3	26%
Lion attack	1	1	–	
Injuries	3	1	2	
Fight with other cheetahs	1	1	–	
Old age	1	–	1	
Total unknown causes	7	4	3	30%

areas, the causes of death varied or were unknown. One case of human persecution was recorded for a translocated male cheetah upon its return to the farmlands where he was captured. Translocation of conflict predators believed to be preying on livestock is perceived as a more humane and publicly acceptable method than lethal control. However, the risk of mortality after translocation is high, with only 18% of translocated cheetahs surviving beyond one year (Boast *et al.*, 2015), as also observed in this dataset. This is likely due to the translocated cheetahs' naivety toward lions (*Panthera leo*) in the areas in which they were translocated to, as lions have been historically extirpated from the majority of farmlands, but exist in high densities at release sites in protected areas (Boast *et al.*, 2015; Winterbach, 2008).

The removal of territorial individuals from carnivore populations has been associated with an increase in the number of subadult or transient individuals in an area (Athreya, 2006; Phillips, Cummings & Berry, 1991). This may result in increased stock losses, and further exacerbate conflict and associated cheetah mortality. Comparative research showed that the impact of translocations has focused on assessing the survival, demography, and space use of translocated individuals (Langridge, Sordello & Reyjol, 2021). However, the impacts on the behaviour, genetics, and physiology, as well as the effects on resident populations at release sites, remain understudied. In light of this low survival rate, associated significant financial costs (averaging \$7110 USD per individual, as calculated by Boast *et al.* 2015) and failure to reduce stock losses, we conclude that the translocation of conflict cheetahs in Botswana should no longer be used as a primary method for tackling human–cheetah conflict, as described by Boast *et al.* (2015). Only one of the deaths in this sample could be confirmed as caused by a fight with a lion, and one of the fatal injuries was suspected to be caused by a lion, although the frequency of lion-induced deaths, especially with translocated individuals, is perhaps higher. However, confirmation of this within our sample was not possible because of the remoteness of collars displaying mortality signals, resulting in considerable time delays before carcasses, and other evidence indicating cause of death could be investigated. This resulted in the fact that for 30% of the mortalities, causes were unknown. In addition, satellite GPS collars used in

this sample often experience time delays related to satellite signal acquisition and automated data transmission (24–120 hours), likely exacerbated by bush encroachment in the study area. Between data acquisition delays and travel time to reach remote locations following mortality signals (travel time up to eight hours), carcasses were often scavenged, making it challenging to conduct a post-mortem and infer cause of death (Wolf, Griffith, Reed & Temple, 1996). It is also possible that transmissions are delayed in cases of mortality when a cheetah falls in a manner that blocks the transmitter from sending a clear signal to the satellite.

We also recorded injuries sustained in the bush. Experienced local trackers, who investigated two of the most recent carcasses in the farmlands, concluded that injuries were sustained by entanglements with thorny bushes during high-speed chases. Bush encroachment is catalysed by unsustainable livestock grazing practices and is common on the farmlands of Botswana and Namibia (Moleele, Ringrose, Matheson & Vanderpost, 2002). The disappearance of native grasses, and the rapid spread of thorny thickets have altered prey biodiversity, prey densities, and visibility and have led to eye injuries in cheetahs (Bauer, 2018; Muntifering *et al.*, 2006; Olaotswe *et al.*, 2013). Furthermore, the farms in the study area are fenced with wire and wooden poles. Although the fencing is permeable to cheetahs, an injury reported was suspected to have been caused by entanglement in a farm fence, but this was never verified. Thus, natural death by fatal injuries (*e.g.* death by infected large wounds) as found by cheetahs in the bush may be influenced by anthropogenic factors.

The high number of mortalities of adult cheetahs in our sample demonstrates that they face both natural and anthropogenic threats across their range, whether on farmlands or in protected areas. In terms of the estimated ages of cheetahs when the mortalities occurred, we observed the same trend as on Namibian farmlands with a high mortality for prime-aged adults (Marker *et al.*, 2003a). Furthermore, we recorded more male than female deaths in proportion to the number of individuals collared. Male cheetahs have larger home ranges and travel longer distances, as has also been observed in the farmlands of Botswana (Houser, Somers & Boast, 2009), and are therefore more susceptible to and more likely to encounter both human-induced and naturally

occurring threats. Although male deaths impact population viability less than female deaths, high human-induced mortality can still disrupt social structure and behaviour (Tuytens & Macdonald, 2000).

Although 23 confirmed mortalities over nearly 20 years may not appear to be disproportionate, they accounted for about half of the collared adult cheetah population. The high mortality of cheetahs in our sample questions the viability of the cheetah population on farmlands. Marker *et al.* (2003a) compared the longevity of cheetahs with and without collars and demonstrated no evidence that putting radio-collars on wild cheetahs increased their chances of premature death following release. Although this suggests that placing collars on the cheetahs in this sample did not increase their vulnerability, cheetahs that were collared and translocated had low survival rates (Boast *et al.*, 2015). Although the use of a soft release has been suggested to increase the chances of a successful translocation, a study in Namibia showed little benefit using soft release methods compared with hard release methods (Weise, Stratford & van Vuuren, 2014). Therefore, we do not expect this to influence our results. However, it is likely that these conflict cheetahs would have been killed by farmers if they had not been translocated (Boast *et al.*, 2015, Cheetah Conservation Botswana, pers. obs.). If adult cheetah mortalities, especially human-induced cheetah mortalities, are so high across Botswana, the sustainability of the national cheetah population could be compromised (Weise *et al.*, 2017). Botswana's geographical location makes it crucial for the connectivity and viability of the southern African cheetah population.

More data on cheetah demographics and population densities are needed on farmland populations in Botswana to investigate whether increased cub survival due to local extirpation of lions and hyaenas (*Crocuta crocuta*) sufficiently offsets human induced mortalities of adults. Cub survival on the farmlands of Namibia, where lions and spotted hyaenas are absent, showed that after 14 months, 79% of cubs survived after emergence from the lair (Wachter *et al.*, 2011), and survival of a few cubs would result in a relatively large percentage increase in population growth (Crooks, Sanjayan & Doak, 1998). When data on birth, survival and reproductive rates are available, population growth rate models could be developed for our region of interest to predict if population

growth can sustain the known mortalities given a specific offtake rate (Weise *et al.*, 2017). This would further assist in developing conservation strategies. In addition, more research into the causes and frequency of mortalities on farmlands is needed to investigate whether human-induced mortalities are threatening these important populations and to improve mitigation measures aimed at protecting cheetahs in southern Africa. Trials involving new tracking technologies that provide live tracking capabilities (such as GSM trackers or those using LoRa networks) would help reduce the response time to mortalities, with prompt carcass investigation improving the ability to accurately identify causes of death. Additionally, new technologies in the form of GPS solar ear tags are currently being trailed on carnivores (Henry, unpubl. data). These smaller, exposed ear tags would be more likely to continue transmitting in cases of a mortality, as opposed to collars, whose transmitters may be blocked by the fallen body. This additional research would complement current conflict mitigation programmes, allow targeted conservation efforts in conflict hotspots, and inform future mitigation activities to reduce human-induced cheetah mortality. Ultimately, the survival of free-ranging cheetah populations across their range depends on the people with whom they share the land and how they respond to the presence of cheetahs and associated conflict events.

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