Aspects of the Ecology and Conservation of Vultures in South Africa

Emma B. Laurieston

Submitted in fulfilment of the academic requirements for the degree of

Master of Science

in the Discipline of Ecological Sciences

School of Life Sciences

College of Agriculture, Engineering and Science

University of KwaZulu-Natal

Pietermaritzburg Campus

2024

ABSTRACT

Vultures play a crucial role in ecosystems as scavengers by consuming carcasses and preventing the spread of diseases. However, vulture populations worldwide face anthropogenic threats causing drastic declines, with several species now facing extinction. In response to this, various conservation efforts have been implemented to safeguard vultures. The overarching goal of this thesis was to evaluate the effectiveness of these conservation efforts through a comprehensive examination of vulture ecology and conservation strategies.

We reviewed the use of questionnaires to understand stakeholder perceptions and global threats to vultures. Additionally, public attitudes towards wildlife marking techniques and the implications for vulture conservation were explored. Furthermore, we evaluated the effectiveness of vulture rehabilitation, release and monitoring initiatives by comparing the behaviour and survival of rehabilitated and wild vultures.

The systematic review of questionnaire-based vulture research revealed critical insights into stakeholder perceptions globally. The study highlighted the multitude of threats facing vultures in different regions. We found worldwide misconceptions among stakeholders, including the belief that vultures attack livestock. These misconceptions exacerbate retaliatory killings, highlighting the need for focused education initiatives to protect vultures. Across Africa, poisoning, poaching, and cultural use of vultures pose significant challenges to their conservation.

The exploration of public perception of wildlife marking techniques, particularly patagial tags on vultures, revealed predominantly positive attitudes towards marking wildlife. Despite broad support for wing-tagging vultures, variations in reporting vulture sightings highlighted the importance of promoting active monitoring and awareness.

Analysis of the Endangered Wildlife Trust Vulture Resighting Database proved patagial tags valuable in collecting long-term data on vulture movements. However, concerns about the

durability of tags and the high number of vultures not resighted after tagging raised questions about their potential impacts on vulture survival. The study of vultures treated at Moholoholo Wildlife Rehabilitation Centre indicated the successful reintroduction of poisoned and injured vultures into the wild despite challenges, including post-release mortality and possible behavioural impacts of the rehabilitation process.

Future research should prioritise tailored conservation strategies, including stricter regulations to limit substances that are harmful to vultures and community-based initiatives for responsible carcass disposal. Increasing public awareness, citizen science projects, and advancements in tracking technology are crucial for improving conservation efforts and halting the decline of vulture populations.

PREFACE

The data described in this thesis were collected in Limpopo, Republic of South Africa, from July 2022 to April 2024. Experimental work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Prof Colleen T. Downs and Dr Lindy J. Thompson.

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, School of Life Sciences, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it is duly acknowledged in the text.

Emma B. Laurieston

June 2024

I certify that the above statement is correct, and as the candidate's supervisor, I have approved this thesis for submission.

……..

Prof Colleen T. Downs

Supervisor

June 2024

COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE

DECLARATION 1 - PLAGIARISM

I, Emma B. Laurieston, declare that:

1. The research reported in this thesis, except where otherwise indicated, is my original research.
2. This thesis has not been submitted for any degree or examination at any other university.
3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.
4. This thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:
    a. Their words have been re-written but the general information attributed to them has been referenced
    b. Where their exact words have been used, then their writing has been placed in italics and inside quotation marks, and referenced.
5. This thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source is detailed in the thesis and in the References sections.

Signed: Emma B. Laurieston

June 2024

COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE

DECLARATION 2 - PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis.

PUBLICATION 1 (not submitted)

A systematic review of questionnaire-based research to assess its value as a research tool and identify trends in vulture conservation

EB Laurieston, LJ Thompson & CT Downs

Author contributions:

EBL conceived the paper with CTD and LJT. EBL collected and analysed data and wrote the paper. CTD and LJT contributed valuable comments to the draft manuscript.

PUBLICATION 2 (not submitted)

Public perception of marking wildlife with monitoring devices for research and conservation purposes

EB Laurieston, LJ Thompson, L Swemmer & CT Downs

Author contributions:

EBL conceived the paper with CTD and LJT. EBL collected and analysed data and wrote the paper. CTD and LJT contributed valuable comments to the draft manuscript.

PUBLICATION 3 (not submitted)

Evaluating the efficacy of vulture rehabilitation and release

EB Laurieston, LJ Thompson, JP Davies, GJ Tate & CT Downs

Author contributions:

EBL conceived the paper with CTD and LJT. LJT, JPD and GJT collected the data. EBL analysed the data and wrote the paper. CTD and LJT contributed valuable comments to the draft manuscript.

Signed: 

Emma B. Laurieston

June 2024

ACKNOWLEDGEMENTS

I extend my sincere appreciation to my supervisors, Prof Colleen T. Downs, and Dr Lindy J. Thompson, for their invaluable guidance and support throughout this thesis. Their expertise has been instrumental in shaping the outcome of this research. Being mentored by such successful women in this field has been truly inspirational.

I thank SANParks and the staff at Kruger National Park for permitting, supporting, and facilitating the data collection process, which was instrumental in gathering valuable information for this study.

I am grateful to the Rufford Foundation for their financial support, which made this project possible. Their commitment to environmental conservation is commendable and has made a significant impact. I am also grateful to the University of KwaZulu-Natal (ZA) and the National Research Foundation (ZA, grant 98404) for funding this research. I thank Idea Wild for their donation of equipment, which greatly enhanced the quality of my work and streamlined the research process.

Special thanks to my family and fiancé for their steadfast support, kind words, and belief in me. Your encouragement has meant the world to me, and I am deeply grateful for your unwavering presence throughout this journey. Lastly, I thank my beloved Jack Russell, Jess, who kept me company, curled up on my lap, for countless hours of desk work.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

Introduction

1.1 Background

Vultures are a diverse group of birds comprising 23 species worldwide (IUCN, 2022). These species are categorised into two groups: Old World vultures and New World vultures. Old World vultures belong to the *Accipitridae* family and are found in Africa, Europe and Asia, while New World vultures are classified under the *Cathartidae* family and inhabit the Americas (Feduccia, 1974; IUCN, 2022). Both groups feed on carrion, and share many adaptations that make them successful scavengers, including a large, broad wingspan optimal for soaring flight (Buechley & Şekercioğlu, 2016; Holmes et al., 2022), and a high stomach acidity that allows the birds to feed on decaying flesh (Roggenbuck et al., 2014; Zou et al., 2021; Chen et al., 2023).

As obligate scavengers, vultures provide critical ecosystem services, such as carcass disposal, nutrient cycling and likely preventing disease transmission (Markandya et al., 2008; Ogada et al., 2012a; Buechley & Şekercioğlu, 2016; Ogada et al., 2016a; Ives et al., 2022; Santangeli et al., 2024). Despite their ecological importance, vulture populations are experiencing severe declines globally, with 11 out of the 23 vulture species classed as endangered or critically endangered (IUCN, 2022), mainly because of anthropogenic threats (Ogada et al., 2012a; Ives et al., 2022).

1.1.1 Causes of vulture declines

One of the main causes of vulture declines in recent years is unintentional poisoning. In the late 1990s and 2000s, the widespread veterinary use of the non-steroidal anti-inflammatory drug, diclofenac, caused populations of vultures in South Asia to decline by over 95% in 10 years (Oaks et al., 2004; Ogada et al., 2016a; Santangeli et al., 2022). Livestock carcasses that

were treated with diclofenac caused fatal kidney failure in the vultures that consumed them (Ogada et al., 2016a; Herrero-Villar et al., 2021). This catastrophic decline, known as the 'Asian Vulture Crisis', had severe ecological consequences, such as an increase in feral dogs (*Canis lupus familaris*), which caused a greater risk of zoonotic diseases such as rabies (Markandya et al., 2008; Naidoo et al., 2009; Santangeli et al., 2019).

Additionally, unintentional poisoning by livestock farmers is another prominent anthropogenic threat to vultures. Stemming from human-wildlife conflicts caused by predators killing their livestock, farmers in many countries have admitted to using poison baits as a method of predator control (Otieno et al., 2011; Plaza et al., 2019; Freitas et al., 2020; Didarali et al., 2022; Dobrev et al., 2022). However, scavengers, such as vultures, often also feed on these baits and are fatally poisoned as a result (Santangeli et al., 2017; Craig et al., 2018). Some farmers also believe that vultures kill their livestock (Mulualem & Tesfahunegny, 2015; Arnulphi & Lambertucci, 2017; Morales-Reyes et al., 2018; Oliva-Vidal et al., 2022), which drives them to poison these birds intentionally. This intentional poisoning causes further declines in vulture populations (Ballejo et al., 2019; Jácome et al., 2022).

Beyond these reasons for poisoning vultures, they are often also killed in an act called sentinel poisoning. This is where poachers, who have committed crimes such as elephant (*Loxodonta africana*) poaching, poison the carcass in an attempt to kill vultures so to prevent them from circling overhead and alerting the authorities to the crime scene (Ogada et al., 2016b; Santangeli et al., 2017; Gore et al., 2020; Daboné et al., 2023). Poachers also poison vultures to sell them into the illegal wildlife trade (Awoyemi et al., 2022), where vulture body parts are sold for traditional medicine and cultural practices (Saidu & Buij, 2013; Mashele et al., 2021b; Mashele et al., 2021a; Manqele et al., 2023).

Another anthropogenic threat to vulture populations is habitat loss. Urbanisation and agricultural expansion are rapidly altering and fragmenting vultures' habitats (Reynolds et al.,

2019). Habitat change not only reduces the areas available for nesting, but also increases the risks of collisions with energy infrastructure such as wind turbines and powerlines (Zuberogoitia et al., 2008). Drowning in unsafe reservoirs is also a problem (Santangeli et al., 2017; Brink et al., 2020). Additionally, changes in land use and improved sanitisation laws, particularly within Europe, have led to a decrease in food availability. Stricter regulations on the disposal of animal carcasses and more efficient carcass removal practices have led to fewer carcasses left in the open, therefore impacting vultures, as they rely on this as a primary food source (Margalida et al., 2010; Henriques et al., 2018).

1.1.2 African vulture species of southern Africa

The combination of these and other threats has driven many vulture species to the brink of extinction (Ogada et al., 2012a; IUCN, 2022). Six of the 11 species of vulture found in Africa are endangered or critically endangered (IUCN, 2022). The White-backed Vulture (*Gyps africanus*), White-headed Vulture (*Trigonoceps tracheliotos*), Rüppell's Vulture (*Gyps rueppelli*), and Hooded Vulture (*Necrosyrtes monachus*) are critically endangered, while the Lappet-faced Vulture (*Torgos tracheliotos*) and Egyptian Vulture *(Neophron percnopterus*) are endangered (IUCN, 2022). African vultures are facing a crisis similar to the Asian Vulture Crisis of the 1990's. Over the past 30 years, African vulture populations have declined by an average of 62%, and seven species were found to have declined at a rate of 80% or more over three generations (Ogada et al., 2016a; Safford et al., 2019), highlighting the urgent need for conservation action to halt these declines and ensure the survival of African vultures.

1.1.3 Conservation efforts

To address the decline of vulture populations in South Africa, provincial conservation agencies and various non-governmental organisations (NGOs) have implemented several conservation

initiatives. These efforts include monitoring vulture populations, providing education to raise awareness, as well as conducting research and advocacy to support vulture conservation (National Vulture Task Force, 2022).

International Vulture Awareness Day (IVAD), organised by the Birds of Prey Programme of the Endangered Wildlife Trust in South Africa and the Hawk Conservancy Trust in the UK, brings global attention to the ecological role of vultures and the severe threats they face. The IVAD aims to raise public awareness about vulture conservation and showcase the efforts of stakeholders. Through coordinated activities and information sharing, the IVAD seeks to garner collective action and support for the protection and conservation of vultures (Department of Forestry, Fisheries and the Environment, 2023; Hawk Conservancy Trust, 2024).

Captive breeding and monitoring programs, such as the Bearded Vulture Recovery Programme, play a crucial role in conserving threatened species in southern Africa (African Raptor Centre, 2022). These initiatives focus on breeding vultures in controlled environments and then releasing them into the wild to boost their populations (Hirschauer et al., 2021). Additionally, monitoring programs track the health, behaviour, and movements of these birds to gather essential data that inform conservation strategies (Wolter et al., 2015). Through these efforts, conservationists aim to stabilise and eventually increase the populations of vulnerable vulture species, ensuring their survival for future generations (Oppel et al., 2021; National Vulture Task Force, 2022).

The establishment of Vulture Safe Zones is a relatively recent conservation initiative designed to collaborate with landowners and secure their support for vulture conservation (Alam & White, 2016; Bhusal, 2018; Kane et al., 2022). This project asks landowners to commit to removing threats to vultures from their properties through various measures (Bhusal, 2018; Kane et al., 2022; National Vulture Task Force, 2022). These include ensuring that all

electricity pylons in the zone are fitted with safeguards or designed to prevent vulture electrocutions and collisions, and modifying water reservoirs to prevent vultures from drowning. Additionally, breeding vultures, whether nesting on cliffs or trees, are protected from disturbances. The initiative also involves providing supplementary food at vulture restaurants that is free from lead and other contaminants, avoiding the use of poison as a deterrent for mammalian predators such as black-backed jackals (*Lupulella mesomelas*) and caracals (*Caracal caracal*), and using lead-free ammunition for the culling of game or euthanising livestock (National Vulture Task Force, 2022; Katzner et al., 2024). Furthermore, all vulture populations within the zones are monitored, and any vulture mortalities are reported to BirdLife South Africa. Through these collaborative efforts, Vulture Safe Zones aim to create safer environments for vultures, supporting their conservation and helping to stabilise and increase their populations (BirdLife South Africa; National Vulture Task Force, 2022).

Poison response training stands out as a critical conservation initiative pioneered by the Hawk Conservancy Trust in partnership with the Endangered Wildlife Trust and the University of Reading (Department of Forestry, Fisheries and the Environment, 2023). Given that poisoning poses the most significant threat to African vultures, untreated incidents could cause local extinctions of vulture populations (Murn & Botha, 2018). Poison response kits and training programs have been strategically deployed to field staff operating in high-risk regions across southern and south-eastern Africa to address this pressing issue. When implemented promptly and effectively, poison response treatment can reduce the mortality rate of vultures at a mass poisoning event by 70% (Murn & Botha, 2018). These initiatives have demonstrated notable success in effectively neutralising poisoned carcasses and mitigating poison-related fatalities (Santangeli et al., 2017; Murn & Botha, 2018).

As a means of monitoring vulture populations, various organisations have developed tagging and marking programs (Wilson, 2015; Curk et al., 2021; National Vulture Task Force,

2022). These initiatives employ methods such as wing-tagging (also called patagial tagging) and leg-ringing to track individual vultures and investigate their behaviour and movements (Kendall & Virani, 2012; Monadjem et al., 2014; Reading et al., 2015; Novaes et al., 2020). Wing-tagging involves attaching lightweight tags to the wings of vultures, typically with unique identification codes, allowing researchers to visually identify and track individuals from a distance (Botha, 2007; Kendall & Virani, 2012; Reading et al., 2015; García-Jiménez et al., 2018; Curk et al., 2021). Leg-ringing, on the other hand, involves fitting vultures with small, numbered rings on their legs, providing a means of long-term identification (Anderson, 2004; Botha, 2007; Curk et al., 2021). These tagging and marking programmes provide valuable insights into vulture ecology, including their foraging patterns, breeding behaviour, migratory routes, and interactions with other individuals and species (Kendall & Virani, 2012; Reading et al., 2015; Novaes et al., 2020). Additionally, wing-tag sighting reports made by the public contribute significantly to these monitoring efforts, enhancing the scope and efficiency of vulture research and conservation initiatives (Santangeli et al., 2020). By monitoring the movements and behaviours of tagged vultures over time, researchers can better understand the factors influencing vulture populations and inform conservation strategies to ensure their long-term survival (Nichols & Williams, 2006; Kendall & Virani, 2012; Perrig et al., 2019).

In addition to monitoring and research efforts, rehabilitation and release programmes play a crucial role in vulture conservation. Organisations dedicated to vulture rehabilitation rescue and treat injured or poisoned vultures, ensuring they receive the necessary care before carefully releasing them back into the wild (Naidoo et al., 2011; Monadjem et al., 2014; Maphalala et al., 2021; Mashele et al., 2022). Through these efforts, rehabilitation and release initiatives aim to contribute to the recovery and sustainability of vulture populations.

1.2 Study area

The study was conducted in north-eastern South Africa, in Limpopo and Mpumalanga Provinces, which are arguably the most important parts of the country for savannah vultures in terms of nesting and foraging habitat (IUCN, 2022). The study area includes the Kruger-to-Canyons (K2C) Biosphere Region, a 2.5 million ha reserve that was registered by UNESCO in 2001, and encompasses the Kruger National Park and the Blyde River Canyon (Linden et al., 2023) (Figure 1.1). This Biosphere Region aims to protect species, landscapes and ecosystems, while encouraging local communities to use ecosystems sustainably (Coetzer et al., 2010; Coetzer et al., 2015). The K2C Biosphere Region has a high level of endemism, including very high concentrations of threatened plant species, and it holds the vast majority of the South African Hooded Vulture population (Allan et al., 2015; IUCN, 2022). Nevertheless, all vulture species found in this area are currently in decline; the Hooded, White-backed, and White-headed Vultures are all Critically Endangered, while the Lappet-faced Vulture is Endangered, and the Cape Vulture is Vulnerable (IUCN, 2022). Traditional Health Practitioners in this area still use vulture body parts in traditional medicine, and there is some evidence of a trade in live vultures (Mashele et al., 2021a; Mashele et al., 2021b). There have also been several poisoning incidents that have resulted in mass deaths of vultures, and sadly, the area is regarded as a vulture poisoning hotspot (Gore et al., 2020).

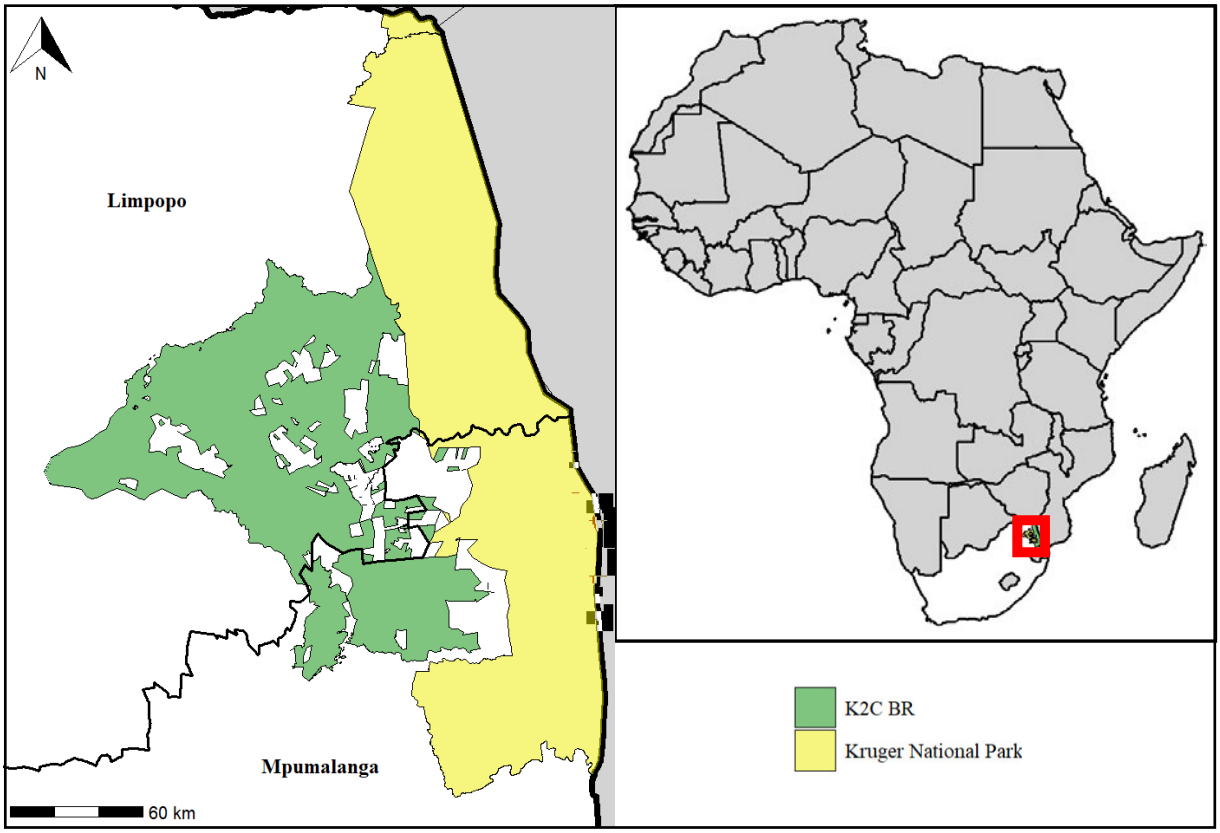


Figure 1.1: Study area encompassing the Kruger National Park and the Kruger-to-Canyon Biosphere Region (K2C BR) in the Limpopo and Mpumalanga Provinces, South Africa.

1.3 Problem statement

Vultures are vital to ecosystems in southern Africa as they clean the environment and may help to prevent disease transmission by consuming carcasses (Ogada et al., 2012b; Buechley et al., 2022). Despite their ecological importance, vulture populations are rapidly declining, primarily because of threats such as poisoning, habitat loss, and poaching for the illegal trade of vulture body parts for traditional medicine (Beilis & Esterhuizen, 2005; Ogada et al., 2012a; Craig et al., 2018; Daboné et al., 2023). Conservation efforts are underway to address these declines, but their effectiveness in the Kruger-to-Canyons (K2C) Biosphere Region has not been robustly studied.

Specifically, the effectiveness of rehabilitating and releasing wing-tagged vultures as a conservation tool in this region has not been studied. Additionally, the perceptions and

knowledge of the public regarding vulture conservation and monitoring efforts, such as wing-tagging, and the public's willingness to participate in reporting sightings of tagged vultures, have not been evaluated. Furthermore, the existing literature on broader public perceptions of vultures and their conservation, including the understanding of threats to vultures and general knowledge about these birds, has not been systematically assessed.

This thesis aims to fill these gaps by systematically reviewing studies that used questionnaires to understand stakeholder attitudes towards vultures, exploring public perceptions and knowledge of vulture conservation efforts, and evaluating the short-term survival and dispersal rates of rehabilitated versus wild-caught vultures. By addressing these issues, we aim to enhance the effectiveness of vulture conservation strategies in southern Africa, particularly within the K2C Biosphere Region.

1.4 Aims and objectives

The main aim of this research project was to evaluate the efficacy of vulture conservation initiatives in the Kruger-to-Canyons Biosphere Region in the Limpopo and Mpumalanga Provinces, South Africa. The objectives of the study were:

a) To conduct a systematic review of global journal articles focusing on vulture ecology and conservation that used questionnaires:
   i. To evaluate the effectiveness of questionnaire-based vulture research.
   ii. To synthesise findings on public perceptions and attitudes towards vulture conservation.
   iii. To identify global threats to vulture populations.

- Prediction: It is predicted that the review will find questionnaire-based research effective in collecting valuable data on vulture ecology and conservation,

highlighting its contributions to understanding public perceptions, attitudes, and key threats to vulture populations.

b) To assess the public perceptions of marking wildlife with monitoring devices for research and conservation purposes.

i. To gauge the public's knowledge of vultures.

ii. To evaluate public awareness of vulture conservation efforts.

iii. To explore public perceptions of marking vultures with wing (patagial) tags for research and conservation purposes.

iv. To assess the willingness of the public to participate in reporting sightings of tagged vultures.

- Null Hypothesis (H0): There is no significant public support or awareness regarding vulture conservation efforts and the use of monitoring devices.
- Alternative Hypothesis (H1): There is significant public support and awareness regarding vulture conservation efforts and the use of monitoring devices.
- Prediction: It is predicted that public support and awareness will be moderate, with some concerns about the welfare implications of monitoring devices but general agreement on their necessity for conservation.

c) To evaluate the efficacy of vulture rehabilitation, release and monitoring in southern Africa.

i. To compare the short-term dispersal distance of rehabilitated vultures with that of wild-caught vultures.

ii. To compare the post-release survival rates of rehabilitated vultures with those of wild-caught vultures.

- Null Hypothesis (H0): There is no significant difference in the post-release outcomes (dispersal distance and survival rates) between rehabilitated vultures and wild-caught vultures.
- Alternative Hypothesis (H1): There is a significant difference in the post-release outcomes (dispersal distance and survival rates) between rehabilitated vultures and wild-caught vultures.
- Prediction: It is predicted that rehabilitated vultures will show comparable post-release dispersal distances and survival rates to wild-caught vultures, indicating the effectiveness of rehabilitation efforts.

1.5 Study outline

The main body of this thesis is organised as draft manuscripts formatted for submission to peer-reviewed scientific journals. The first chapter (Chapter 1) is the Introduction, which provides a literature review of the concepts covered in this study. The next three chapters (Chapters 2, 3, and 4) are empirical chapters, each covering a specific objective. The hypotheses and/ or predictions are presented in each. Each of these chapters is formatted according to the requirements of the journal it is intended to be submitted to. Because of this thesis format, a certain degree of repetition, especially in the methods section, was unavoidable. However, this is deemed to be of little concern as this format allows the reader to read each chapter separately without losing the overall context of the thesis.

The chapters are arranged as follows:

Chapter 2: A systematic review of questionnaire-based research to assess its value as a research tool and identify trends in vulture conservation

Chapter 3: Public perceptions of marking wildlife with monitoring devices for research purposes

Chapter 4: Assessing conservation strategies for vultures: Rehabilitation, release, and patagial tagging

Chapter 5: General discussion, conclusions and recommendations.

1.6 References

African Raptor Centre. (2022). *The Bearded Vulture Breeding Program*. https://africanraptor.co.za/homepage/the-bearded-vulture-conservation-project/

Alam, A. S. (2016). Establishment and management of community-based Vulture Safe Zones (VSZ) in Bangladesh. In *Proceedings of the Regional Symposium on Vulture Conservation in Asia* (pp. 33-38), Pakistan. https://www.researchgate.net/publication/343181729_vulture_symposium_proceedings_2016_1

Allan, D. (2015). Hooded Vulture *Necrosyrtes monachus*. In M. P. Taylor, F. Peacock & R. M. Wanless, (Eds), *The 2015 Eskom Red Data Book of Birds of South Africa*, (pp. 58-60), Birdlife South Africa, Johannesburg.

Colahan, B. D. (2004). The status and conservation of vultures in the Free State Province of South Africa. In A. Monadjem, M. D. Anderson, S. E. Piper, & A. F. Boshoff (Eds), *The Vultures of Southern Africa – Quo Vadis?* (pp. 81-86), Birds of Prey Working Group, Endangered Wildlife Trust, South Africa.

Arnulphi, C., & Lambertucci, V. B., Borghi, S. A., Carlos E. (2017). Education can improve the negative perception of a threatened long-lived scavenging bird, the Andean condor. *PLoS One*, *12*(9), e0185278. https://doi.org/10.1371/journal.pone.0185278

Awoyemi, S. M., Thomas-Walters, L., Anthony, B. P., Vyas, D., Buij, R., & Amusa, T. O. (2022). Culture and the illegal trade in vultures in southwestern Nigeria: conundrums and recommendations. *Vulture News*, *83*, 18-31.

Ballejo, F., Grilli, M. G., & Lambertucci, S. A. (2019). A long and troublesome journey: People's perceptions and attitudes along the migratory path of a scavenger bird. *Ethnobiology and Conservation*, *8*, 13.

Beilis, N., & Esterhuizen, J. (2005). The potential impact on Cape Griffon *Gyps coprotheres* populations due to the trade in traditional medicine in Maseru, Lesotho. *Vulture News*, *53*, 15-19.

Bhusal, K. P. (2018). Vulture Safe Zone: a landscape level approach to save the threatened vultures in Nepal. *Himalayan Naturalist*, *1*(1), 25-26.

BirdLife South Africa (n.d.). *Vultures - Raptors*. https://www.birdlife.org.za/what-we-do/species-conservation/what-we-do/raptors/vultures/#:~:text=What%20is%20a%20Vulture%20Safe,to%20the%20vulture%20species%20present.

Botha, A. (2007). A review of colour-marking techniques used on vultures in southern Africa. *Vulture News*, *56*, 52-63.

Brink, C. W., Santangeli, A., Amar, A., Wolter, K., Tate, G., Krüger, S., Tucker, A. S., & Thomson, R. L. (2020). Perceptions of vulture supplementary feeding site managers and potential hidden risks to avian scavengers. *Conservation Science and Practice*, *2,* e237. https://doi.org/10.1111/csp2.237

Buechley, E. R., Murgatroyd, M., Ruffo, A. D., Bishop, R. C., Christensen, T., Marra, P. P., Sillett, T. S., & Şekercioğlu, Ç. H. (2022). Declines in scavenging by endangered vultures in the Horn of Africa. *Journal of Wildlife Management*, *86*, e22194. . https://doi.org/10.1002/jwmg.22194

Buechley, E. R., & Şekercioğlu, Ç. H. (2016). The avian scavenger crisis: Looming extinctions, trophic cascades, and loss of critical ecosystem functions. *Biological Conservation*, *198*, 220-228.

Chen, Y., Xiang, L., Chen, P., & Zhao, H. (2023). Vultures as a model for testing molecular adaptations of dietary specialization in birds. *Avian Research*, *14,* 100128. https://doi.org/10.1016/j.avrs.2023.100128

Coetzer, K., Witkowski, E., & Erasmus, B. (2015). Biosphere reserves as multi-use conservation landscapes: Perspectives from the Kruger to Canyons Biosphere Reserve, South Africa. *South African Journal of Botany*, *98*, 208.

Coetzer, K. L., Erasmus, B. F., Witkowski, E., & Bachoo, A. K. (2010). Land-cover change in the Kruger to Canyons Biosphere Reserve (1993-2006): A first step towards creating a conservation plan for the subregion. *South African Journal of Science*, *106*(7), 1-10.

Craig, C. A., Thomson, R. L., & Santangeli, A. (2018). Communal farmers of Namibia appreciate vultures and the ecosystem services they provide. *Ostrich*, *89*(3), 211-220.

Curk, T., Scacco, M., Safi, K., Wikelski, M., Fiedler, W., Kemp, R., & Wolter, K. (2021). Wing tags severely impair movement in African Cape Vultures. *Animal Biotelemetry*, *9*(1), 1-13.

Daboné, C., Ouéda, A., Thompson, L. J., Adjakpa, J. B., & Weesie, P. D. (2023). Trade in vulture parts in West Africa: Burkina Faso may be one of the main sources of vulture carcasses. *Bird Conservation International*, *33*, e8. https://doi.org/10.1017/S095927092100054X

Department of Forestry, Fisheries and the Environment. (2023). *Forestry, Fisheries and the Environment marks International Vulture Awareness Day 2023*. https://www.gov.za/news/media-statements/forestry-fisheries-and-environment-marks-international-vulture-awareness-day

Didarali, Z., Kuiper, T., Brink, C. W., Buij, R., Virani, M. Z., Reson, E. O., & Santangeli, A. (2022). Awareness of environmental legislation as a deterrent for wildlife crime: A case with Masaai pastoralists, poison use and the Kenya Wildlife Act. *Ambio*, *51*(7), 1632-1642.

Dobrev, V., Topi, M., Hallmann, B., Dobrev, D., Arkumarev, V., Saravia-Mullin, V., Bounas, A., Pappaionnou, H., Bino, T., & Duro, K. (2022). Status and Threats for the Egyptian Vulture *Neophron percnopterus* (Linnaeus, 1758) in Albania. *Acta Zoologica Bulgaria*, 11-18.

Feduccia, A. (1974). Another Old World vulture from the New World. *Wilson Bulletin*, *86*(3), 251-255.

Freitas, R., Monteiro, C., Rodrigues, I., Tavares, A., Monteiro, G., Lopez, P., Martins, S., Ferreira, J., Lima, L., & Tavares, J. P. (2020). Cabo Verde Egyptian Vulture *Neophron percnopterus* on the brink: community perceptions, inferences and facts of an extreme population crash. *Bird Conservation International*, *30*(2), 289-307.

García-Jiménez, R., Pérez-García, J. M., & Margalida, A. (2018). Drivers of daily movement patterns affecting an endangered vulture flight activity. *BMC Ecology*, *18*, 1-15.

Gore, M. L., Hübschle, A., Botha, A. J., Coverdale, B. M., Garbett, R., Harrell, R. M., Krüger, S. C., Mullinax, J. M., Olson, L. J., & Ottinger, M. A. (2020). A conservation criminology-based desk assessment of vulture poisoning in the Great Limpopo Transfrontier Conservation Area. *Global Ecology and Conservation*, *23*, e01076. https://doi.org/10.1016/j.gecco.2020.e01076

Hawk Conservancy Trust. (2024). *Poison Response Action - Another Continental Vulture Crisis*. https://www.hawk-conservancy.org/prk/

Henriques, M., Granadeiro, J. P., Monteiro, H., Nuno, A., Lecoq, M., Cardoso, P., Regalla, A., & Catry, P. (2018). Not in wilderness: African vulture strongholds remain in areas with high human density. *PLoS One*, *13*(1), e0190594. https://doi.org/10.1371/journal.pone.0190594

Herrero-Villar, M., Delepoulle, É., Suárez-Regalado, L., Solano-Manrique, C., Juan-Sallés, C., Iglesias-Lebrija, J. J., Camarero, P. R., González, F., Álvarez, E., & Mateo, R. (2021). First diclofenac intoxication in a wild avian scavenger in Europe. *Science of the Total Environment*, *782*, 146890. https://doi.org/10.1016/j.scitotenv.2021.146890

Hirschauer, M. T., Hannweg, C. G., Kemp, R., & Wolter, K. (2021). VulPro: an overview of Africa's vulture conservation centre. *Vulture News*, *81*, 9-24.

Holmes, J., Sustaita, D., & Hertel, F. (2022). Geometric morphometric analysis of the humerus in New and Old World vultures. *Journal of Morphology*, *283*(4), 379-394.

IUCN. (2022). *Vultures,* IUCN Red List. https://www.iucnredlist.org/search?query=vulture&searchType=species

Ives, A. M., Brenn-White, M., Buckley, J. Y., Kendall, C. J., Wilton, S., & Deem, S. L. (2022). A global review of causes of morbidity and mortality in free-living vultures. *EcoHealth*, *19*(1), 40-54.

Jácome, N. L., Abarzua, G., Astore, V., & Estrada Pacheco, R. (2022). Mass poisonings of the Vulnerable Andean condor prompt national strategy against the use of toxic baits in Argentina. *Ethnobiology and Conservation*, *11*, 14.

Kane, A., Monadjem, A., Aschenborn, H. O., Bildstein, K., Botha, A., Bracebridge, C., Buechley, E. R., Buij, R., Davies, J. P., & Diekmann, M. (2022). Understanding continent-wide variation in vulture ranging behavior to assess feasibility of Vulture Safe Zones in Africa: Challenges and possibilities. *Biological Conservation*, *268*, 109516. https://doi.org/10.1016/j.biocon.2022.109516

Katzner, T. E., Pain, D. J., McTee, M., Brown, L., Cuadros, S., Pokras, M., Slabe, V. A., Watson, R. T., Wiemeyer, G., & Bedrosian, B. (2024). Lead poisoning of raptors: state of the science and cross-discipline mitigation options for a global problem. *Biological Reviews of the Cambridge Philosophical Society*. https://doi.org/10.1111/brv.13087

Kendall, C. J., & Virani, M. Z. (2012). Assessing mortality of African vultures using wing tags and GSM-GPS transmitters. *Journal of Raptor Research*, *46*(1), 135-140.

Linden, E., Rittenhouse, C. D., Peel, M. J., Ortega, I. M., & Smit, I. P. (2023). Vegetation changes following large-scale fence removal across a protected area network within the Kruger to Canyons Biosphere Reserve, South Africa. *Ecosystems*, *26*(4), 768-783.

Manqele, N. S., Selier, S. J., & Downs, C. T. (2023). The ethnomedicinal use of vultures by traditional health practitioners in KwaZulu-Natal, South Africa. *Journal of Ornithology*, *164*(4), 777-788.

Maphalala, M. I., Monadjem, A., Bildstein, K. L., Hoffman, B., & Downs, C. (2021). Causes of admission to a raptor rehabilitation centre and factors that can be used to predict the likelihood of release. *African Journal of Ecology*, *59*(2), 510-517.

Margalida, A., Donazar, J. A., Carrete, M., & Sánchez-Zapata, J. A. (2010). Sanitary versus environmental policies: fitting together two pieces of the puzzle of European vulture conservation. *Journal of Applied Ecology*, *47*(4), 931-935.

Markandya, A., Taylor, T., Longo, A., Murty, M., Murty, S., & Dhavala, K. (2008). Counting the cost of vulture decline—an appraisal of the human health and other benefits of vultures in India. *Ecological Economics*, *67*(2), 194-204.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021a). Traditional health practitioners' and other community members' perceptions of vultures in the Kruger to Canyons biosphere region, South Africa. *Journal of Raptor Research*, *55*(3), 340-358.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2022). Trends in the admission of raptors to the Moholoholo Wildlife Rehabilitation Centre, Limpopo province, South Africa. *African Zoology*, *57*(1), 56-63.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021b). Uses of Vultures in Traditional Medicines in the Kruger to Canyons Biosphere Region, South Africa. *Journal of Raptor Research*, *55*(3), 328-339.

Monadjem, A., Wolter, K., Neser, W., & Kane, A. (2014). Effect of rehabilitation on survival rates of endangered Cape vultures. *Animal Conservation*, *17*(1), 52-60.

Morales-Reyes, Z., Martín-López, B., Moleón, M., Mateo-Tomás, P., Botella, F., Margalida, A., Donázar, J. A., Blanco, G., Pérez, I., & Sánchez-Zapata, J. A. (2018). Farmer perceptions of the ecosystem services provided by scavengers: what, who, and to whom. *Conservation Letters*, *11*(2), e12392. doi: 10.1111/conl.12392

Mulualem, G., & Tesfahunegny, W. (2015). Depredation of domestic fowl by birds of prey in low income rural households of Alamata Wereda, Southern Tigray, Ethiopia. *Journal of Zoology Studies*, *2*(5), 22-29.

Murn, C., & Botha, A. (2018). A clear and present danger: impacts of poisoning on a vulture population and the effect of poison response activities. *Oryx*, *52*(3), 552-558.

Naidoo, V., Wolter, K., Cuthbert, R., & Duncan, N. (2009). Veterinary diclofenac threatens Africa's endangered vulture species. *Regulatory Toxicology and Pharmacology*, *53*(3), 205-208.

Naidoo, V., Wolter, K., Espied, I., & Kotze, A. (2011). Vulture rescue and rehabilitation in South Africa: An urban perspective. *Journal of the South African Veterinary Association*, *82*(1), 24-31.

National Vulture Task Force. (2022). *Draft Biodiversity Management Plan (BMP) for the Conservation of Seven Vulture Species in South Africa*. South African Government Gazette, 47632, 70-71. https://www.dffe.gov.za/sites/default/files/sites/default/files/docs/publications/nemba_multispecies.bmp_southafricanvultures_g47632gon2817.pdf

Nichols, J. D., & Williams, B. K. (2006). Monitoring for conservation. *Trends in Ecology & Evolution*, *21*(12), 668-673.

Novaes, W. G., Abreu, T. L. d. S., & Guerta, R. S. (2020). Assessing vulture translocation as a management tool to mitigate airport bird strikes. *Human–Wildlife Interactions*, *14*(2), 19.

Oaks, J. L., Gilbert, M., Virani, M. Z., Watson, R. T., Meteyer, C. U., Rideout, B. A., Shivaprasad, H., Ahmed, S., Iqbal Chaudhry, M. J., & Arshad, M. (2004). Diclofenac residues as the cause of vulture population decline in Pakistan. *Nature*, *427*(6975), 630-633.

Ogada, D., Botha, A., & Shaw, P. (2016a). Ivory poachers and poison: drivers of Africa's declining vulture populations. *Oryx*, *50*(4), 593-596.

Ogada, D., Keesing, F., & Virani M, Z. (2012a). Dropping dead: causes and consequences of vulture population declines worldwide. *Annals of the New York Academy of Sciences*, *1249*(1), 57-71.

Ogada, D., Shaw, P., Beyers, R. L., Buij, R., Murn, C., Thiollay, J. M., Beale, C. M., Holdo, R. M., Pomeroy, D., & Baker, N. (2016b). Another continental vulture crisis: Africa's vultures collapsing toward extinction. *Conservation Letters*, *9*(2), 89-97.

Ogada, D., Torchin, M., Kinnaird, M., & Ezenwa, V. (2012b). Effects of vulture declines on facultative scavengers and potential implications for mammalian disease transmission. *Conservation Biology*, *26*(3), 453-460.

Oliva-Vidal, P., Hernández-Matías, A., García, D., Colomer, M. À., Real, J., & Margalida, A. (2022). Griffon vultures, livestock and farmers: Unraveling a complex socio-economic ecological conflict from a conservation perspective. *Biological Conservation*, *272*, 109664. https://doi.org/10.1016/j.biocon.2022.109664

Oppel, S., Saravia, V., Bounas, A., Arkumarev, V., Kret, E., Dobrev, V., Dobrev, D., Kordopatis, P., Skartsi, T., & Velevski, M. (2021). Population reinforcement and demographic changes needed to stabilise the population of a migratory vulture. *Journal of Applied Ecology*, *58*(12), 2711-2721.

Otieno, P. O., Lalah, J. O., Virani, M., Jondiko, I. O., & Schramm, K.-W. (2011). Carbofuran use and abuse in Kenya: residues in soils, plants, water courses and the African white-backed vultures (*Gyps africanus*) found dead. *Environmentalist*, *31*, 382-393.

Perrig, P. L., Lambertucci, S. A., Donadio, E., Padró, J., & Pauli, J. N. (2019). Monitoring vultures in the 21st century: The need for standardized protocols. *Journal of Applied Ecology, 56*, 796–801.

Plaza, P. I., Martínez-López, E., & Lambertucci, S. A. (2019). The perfect threat: Pesticides and vultures. *Science of the Total Environment*, *687*, 1207-1218.

Reading, R. P., Maude, G., Hancock, P., Kenny, D., & Garbett, R. (2015). Comparing different types of patagial tags for use on vultures. *Vulture News*, *67*(2), 33-42.

Reynolds, J., Ibáñez-Álamo, J. D., Sumasgutner, P., & Mainwaring, M. C. (2019). Urbanisation and nest building in birds: a review of threats and opportunities. *Journal of Ornithology*, *160*(3), 841-860.

Roggenbuck, M., Bærholm Schnell, I., Blom, N., Bælum, J., Bertelsen, M. F., Sicheritz-Pontén, T., Sørensen, S. J., Gilbert, M. T. P., Graves, G. R., & Hansen, L. H. (2014). The microbiome of New World vultures. *Nature Communications*, *5*(1), 5498.

Safford, R., Andevski, J., Botha, A., Bowden, C. G., Crockford, N., Garbett, R., Margalida, A., Ramírez, I., Shobrak, M., & Tavares, J. (2019). Vulture conservation: the case for urgent action. *Bird Conservation International*, *29*(1), 1-9.

Saidu, Y., & Buij, R. (2013). Traditional medicine trade in vulture parts in northern Nigeria. *Vulture News*, *65*, 4-14.

Santangeli, A., Arkumarev, V., Komen, L., Bridgeford, P., & Kolberg, H. (2017). Unearthing poison use and consequent anecdotal vulture mortalities in Namibia's commercial farmland–implications for conservation. *Ostrich*, *88*(2), 147-154.

Santangeli, A., Girardello, M., Buechley, E., Botha, A., Minin, E. D., & Moilanen, A. (2019). Priority areas for conservation of Old World vultures. *Conservation Biology*, *33*(5), 1056-1065.

Santangeli, A., Lambertucci, S. A., Margalida, A., Carucci, T., Botha, A., Whitehouse-tedd, K., & Cancellario, T. (2024). The global contribution of vultures towards ecosystem services and sustainability–an experts' perspective. *iScience*, *27*, 109925. https://doi.org/10.1016/j.isci.2024.109925

Santangeli, A., Pakanen, V.-M., Bridgeford, P., Boorman, M., Kolberg, H., & Sanz-Aguilar, A. (2020). The relative contribution of camera trap technology and citizen science for estimating survival of an endangered African vulture. *Biological Conservation*, *246*, 108593. https://doi.org/10.1016/j.biocon.2020.108593

Santangeli, A., Virani, M. Z., & Margalida, A. (2022). The hidden damage of dogs to biodiversity–Dog poisoning hampers vulture conservation. *Biological Conservation*, *268*, 109434. https://doi.org/10.1016/j.biocon.2022.109505

Wilson, B. (2015). An introduction to camera trapping of wing-tagged vultures in southern Africa. *Vulture News*, *69*, 3-22.

Wolter, K., Neser, W., & Hirschauer, M. (2015). *Cape vulture (Gyps coprotheres) Captive-Breeding Protocols*, VulPro, South Africa.

Zou, D., Tian, S., Zhang, T., Zhuoma, N., Wu, G., Wang, M., Dong, L., Rossiter, S. J., & Zhao, H. (2021). Vulture genomes reveal molecular adaptations underlying obligate scavenging and low levels of genetic diversity. *Molecular Biology and Evolution*, *38*(9), 3649-3663.

Zuberogoitia, I., Zabala, J., Martínez, J., Martínez, J., & Azkona, A. (2008). Effect of human activities on Egyptian vulture breeding success. *Animal Conservation*, *11*(4), 313-320.

CHAPTER 2

A systematic review of questionnaire-based research to assess its value as a research tool and identify trends in vulture conservation

Emma B. Laurieston[1], Lindy J. Thompson[1,2,3], and Colleen T. Downs[*1]

[1]*Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg, 3209, South Africa*

[2]*Birds of Prey Programme, Endangered Wildlife Trust, Midrand, South Africa*

[3]*Southern African Wildlife College, Kempiana Nature Reserve, Hoedspruit, South Africa*

Formatted as a manuscript for submission to an international peer-reviewed journal.

* Corresponding author: Colleen T. Downs

Email: downs@ukzn.ac.za; ORCID: http://orcid.org/0000-0001-8334-1510

Emails and ORCIDs of other authors:

Emma B. Laurieston Email: emmalaurieston4@gmail.com; ORCID: https://orcid.org/0009-0009-4157-2359

Lindy Thompson Email: lindyt@ewt.org.za; ORCID: https://orcid.org/0000-0001-9847-2003

2.1 Abstract

Vulture populations worldwide are facing significant anthropogenic threats, leading to drastic declines in their numbers. Questionnaires have emerged as an effective tool in ecological research, capturing the thoughts, experiences, and perceptions of the public and stakeholders on various ecological topics. Our systematic review aims to examine the existing literature on vulture ecology that used questionnaires. We found that the use of questionnaire studies in vulture research has been invaluable in gathering insights into the perceptions, experiences, thoughts, and concerns of key stakeholders in vulture conservation. These studies reveal how different groups view vultures, informing outreach and education efforts aimed at fostering positive attitudes and reducing negative interactions. The questionnaires also identified important cultural beliefs and practices impacting vulture populations globally, providing essential information for designing culturally sensitive conservation strategies. Additionally, involving the public in surveys and interviews fosters community engagement and ownership of conservation initiatives, which is crucial for long-term success. Future research should expand questionnaire studies to other understudied countries and focus on vulnerable, endangered, and critically endangered vulture species, while addressing public concerns such as livestock attacks to inform targeted conservation efforts. Education initiatives should be prioritised to raise awareness about the ecological importance of vultures and promote their conservation among the general public.

Keywords: Vulture conservation, Anthropogenic threats, Questionnaires, Public perception

2.2 Introduction

Questionnaires are a common tool used in social science research to collect data on participants' behaviour, attitudes, beliefs, and social characteristics (Bulmer, 2004; Bird, 2009). Recently, their use in ecological research has increased because of their effectiveness in capturing the thoughts, experiences and perceptions of the public and stakeholders on various ecological topics (White et al., 2005; Van et al., 2020). By enabling researchers to integrate ecological data with social, economic, and cultural information, questionnaires allow for a comprehensive examination of complex conservation challenges. Understanding public opinions, attitudes, and perceptions is particularly important when studying species that face anthropogenic threats (Liordos et al., 2017). Their perspectives offer valuable insights into the drivers of negative interactions between humans and wildlife (Basak et al., 2022).

Vulture populations worldwide face numerous anthropogenic threats, including intentional and unintentional poisoning, poaching, wildlife trafficking, use in traditional medicine, habitat loss, collisions with energy infrastructure, and direct persecution (Ogada et al., 2012; Ives et al., 2022). Questionnaires have been used in numerous studies to assess threats to vultures, as well as public perceptions, attitudes, and behaviours related to vulture conservation (Baral & Gautam, 2007; Arnulphi & Lambertucci, 2017; Morales-Reyes et al., 2019). By engaging stakeholders and local communities, questionnaire-based studies provide insights into human-wildlife interactions, anthropogenic threats, and conservation priorities (White et al., 2005).

Although questionnaire-based research is used in vulture conservation, its value as a research tool has not been comprehensively evaluated. Our systematic review aimed to address this gap by examining the existing literature on vulture ecology that used questionnaires. We sought to assess the effectiveness of questionnaires as a tool in vulture research and conservation, evaluating their benefits and limitations. Additionally, this review synthesised

findings on public perceptions and attitudes towards vulture conservation, revealing how different stakeholder groups perceived vultures and their conservation needs. Furthermore, the review identified key global threats to vulture populations as reported through these studies. We predicted that questionnaire-based research would reveal significant insights into public perceptions and attitudes towards vulture conservation and highlight key anthropogenic threats identified by various stakeholder groups.

2.3 Methods

2.3.1 Data collection

We conducted a global literature search to identify and evaluate questionnaire-based research related to vulture studies. We used multiple databases, including Scopus®, Web of Science®, Wildlife and Ecology Studies Worldwide®, and Google Scholar® to identify peer-reviewed journal articles on vultures that employed questionnaires in their methodology. The search was conducted on 5 December 2023. Due to variations in the advanced search functionalities of each database, slight modifications were made to the search strings (Supplementary Information Table S2.1). However, to maintain consistency in the search process across the different databases, we ensured that the search terms remained the same. For Google Scholar, given its vast database and potential for returning numerous results, we limited our search to the first 30 pages, resulting in 300 papers. We then excluded those not relevant to our study based on the inclusion and exclusion criteria outlined below.

2.3.2 Inclusion and exclusion criteria

We included peer-reviewed journal articles that used questionnaires as part of their methodology and involved some aspect related to vultures. The review considered studies published in English from any time period up to 5 December 2023. In our search, we used the

terms “vulture” and “condor,” as well as the scientific names of all 23 vulture species found globally. We also included terms such as “questionnaire,” “survey,” and “interview.” The search was not limited by country or date to ensure all relevant articles were gathered. To further refine our search and avoid including studies focused on land or aerial surveys rather than questionnaire surveys, we specifically excluded terms such as "road transect”, "aerial", and "field."

We excluded studies that lacked sufficient detail, such as those that focused on many species of animals and only briefly mentioned vultures. Additionally, duplicate publications and studies that were not relevant to either vultures or questionnaire-based surveys or interviews were excluded from this review.

2.3.3 Data screening

In the screening process, we followed the PRISMA guidelines (Page et al., 2021). We initially screened articles by reviewing their titles and abstracts to identify potentially relevant studies. Articles that appeared to meet the inclusion criteria based on this initial screening were then selected for full-text review. During the full-text review stage, we carefully read through the entire text of each potentially relevant article to determine if it met all inclusion criteria (Supplementary Information Figure S2.1). This screening process ensured that only eligible studies meeting the predefined criteria were included in the systematic review.

2.3.4 Data Synthesis and Categorisation

In the data synthesis stage, we systematically extracted relevant information from each publication. This information typically included details about the study site and design, methodology, participant demographics, the conservation issue that the study focused on, focus species’, key findings, public perceptions of vultures, knowledge gaps, and author

recommendations for future research. We organised these extracted data in a structured format on Microsoft Excel to facilitate analysis and comparison across studies.

To sort and categorise the extracted data, we developed a framework covering themes and variables relevant to both vulture conservation and questionnaire-based research. This framework helped us to organise the data into meaningful categories, such as stakeholder group, vulture species studied, type of questionnaire used, key themes, key findings, and implications for conservation efforts. Each study was assigned two categories based on two main themes of the questionnaire. This approach was adopted because some studies focused on more than one conservation issue. To identify common themes within the studies, we conducted a text analysis (Ryan and Bernard, 2000), focusing particularly on the introduction and methods sections where the focus of the interview or survey was described. We began with word repetition analysis to identify frequently occurring terms, such as "perception," "NSAIDs," and "poisoning." By examining how these terms were used in context, we performed a thematic analysis to recognise overarching themes commonly studied in the papers. Using this information, we categorised each study into its primary and secondary themes, based on the main issues addressed in the research. This methodical approach ensured that we accurately captured the key topics and recurring themes central to each study's research focus and objectives. All authors agreed upon the themes identified.

2.3.5 Statistical analyses

In our analyses, we used both inferential and descriptive statistics to identify trends and patterns in questionnaire-based vulture conservation. We conducted a linear regression analysis using R (version 4.2.1, R Core Team, 2022) to evaluate the temporal distribution of studies, and assess if there were significant differences in publication frequencies over time. A Chi-squared Kruskal-Wallis test was conducted to examine the relationship between conservation status of

vultures and the number of studies carried out. Additionally, descriptive statistics, including percentages and frequency counts, were calculated using R (version 4.2.1, R Core Team, 2022) to analyse the data. Furthermore, we listed the perceptions mentioned in each study and used R to create a word cloud, visually representing the most frequently mentioned perceptions and concerns regarding vulture conservation.

2.4 Results

Our initial literature search across four databases, Web of Science®, Scopus®, Wildlife & Ecology Studies Worldwide®, and Google Scholar®, yielded a total of 9,226 papers (464 from Web of Science®, 227 from Scopus®, 695 from Wildlife and Ecology Studies Worldwide®, and 7,840 from Google Scholar®, which was capped at the first 30 pages, resulting in 300 studies). After screening titles and abstracts, this number was reduced to 453 papers (102 from Web of Science®, 83 from Scopus®, 64 from Wildlife and Ecology Studies Worldwide®, and 203 from Google Scholar®). Within each database, a total of 11 duplicate papers were identified and removed, leaving us with 441 unique papers across all databases. Following additional screening for relevance and sufficiency of information, 137 papers were excluded for not meeting the inclusion criteria and 28 for insufficient information, resulting in a final total of 114 papers included in the review (Supplementary Information Table S2.2).

2.4.1 Temporal trends in questionnaire-based vulture research

From the literature search, the earliest questionnaire study focusing on vultures dated back to 1974. Since then, there was a significant increase in research activity, particularly in recent years ($R^2 = 0.41$, $F(1, 22) = 17.12$, $p < 0.001$). The number of studies conducted has shown a substantial rise, reaching as high as 14 studies in 2019 and 2021 (Figure 2.1).

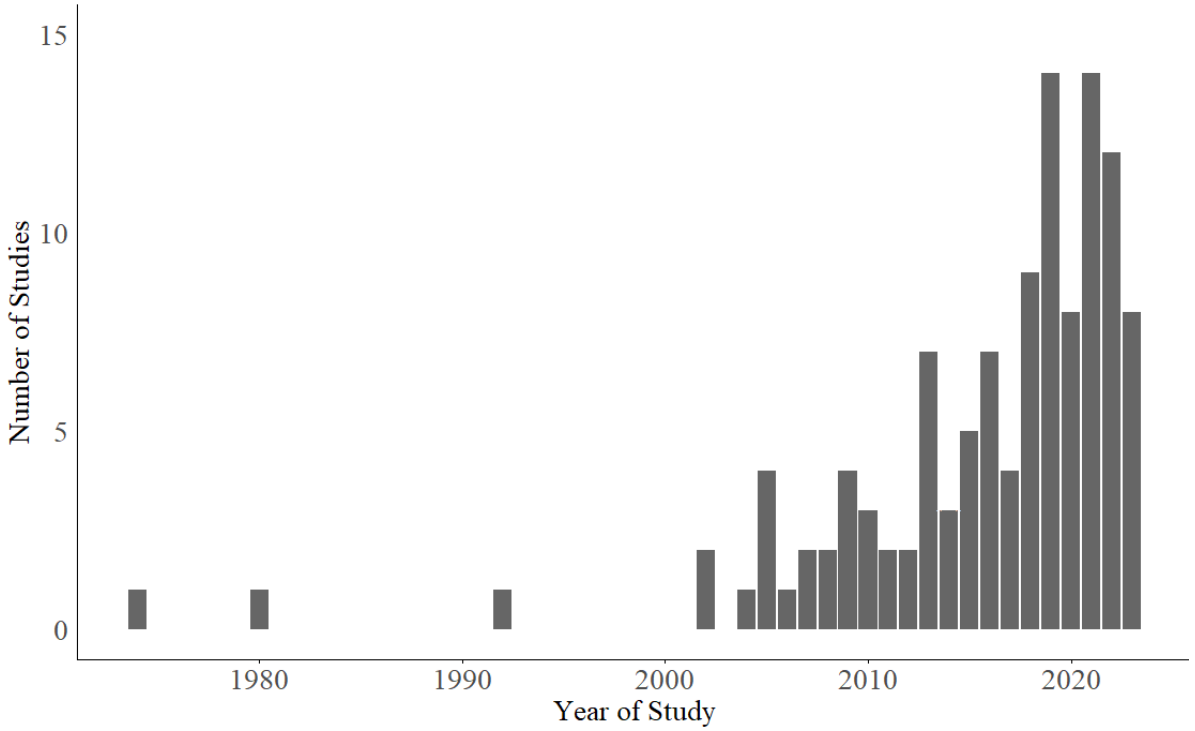


Figure 2.1: Trend in number of publications of questionnaire-based vulture studies over time.

2.4.2 Geographical distribution of vulture questionnaire studies

In our study we found that questionnaire-based studies focusing on vultures were conducted across 38 countries in five continents (Figure 2.2). Among the most frequently studied countries were South Africa, India, Nigeria, and Nepal, each hosting a notable number of studies (15, 12, 12, and 12 studies, respectively). There was a widespread distribution of questionnaire-based vulture studies; however, several countries where vultures inhabit have not yet been studied (Supplementary Information Table S2.2).

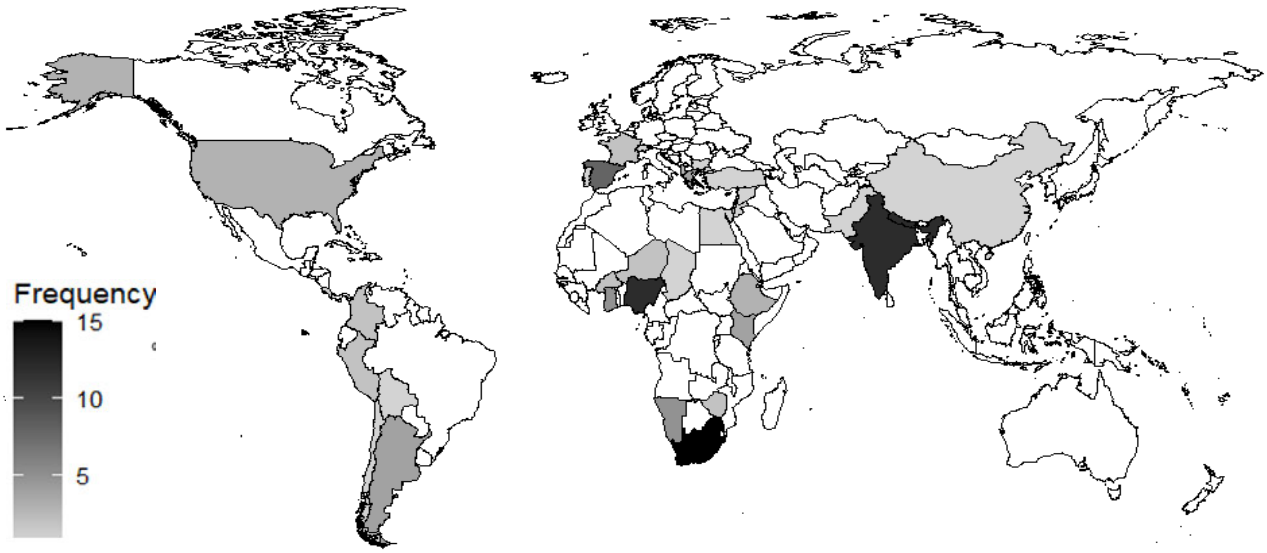


Figure 2.2: The geographical distribution of questionnaire studies on vultures across different countries. The intensity of colour represents the number of studies conducted in each country, with darker shades indicating higher frequencies.

2.4.3 Research attention across vulture species

Exploring the questionnaire-based vulture research, we observed a diverse distribution of research attention across different vulture species (Table 2.1). From the publications reviewed, a total of 21 out of 23 vulture species received research attention, with at least one study per species. Species such as the Egyptian Vulture (*Neophron percnopterus*) and Hooded Vulture (*Necrosyrtes monachus*) received the most attention, with 30 and 27 studies conducted on each, respectively. Similarly, the White-backed Vulture (*Gyps africanus*) and White-rumped Vulture (*Gyps bengalensis*) received significant research interest, with 23 and 17 studies related to them, respectively. Our analysis revealed a significant relationship between the conservation status of species and the number of studies conducted. Specifically, we found that species classified as more threatened (e.g., 'Critically Endangered' or 'Endangered') tended to be the focus of more studies than those classified as 'Least Concern' or 'Near Threatened.' ($\chi^2 = 9.63$, df = 4, p = 0.047). In addition, our analysis revealed disparities in research attention between

Old World and New World vultures. Old World vultures received notably more research attention, with a mean number of 14 studies per species, compared with New World vultures, which had a mean of only 1 study per species. Furthermore, two species, the King Vulture (*Sarcoramphus papa*) and the Greater Yellow-headed Vulture (*Cathartes melambrotus*) were not mentioned in any questionnaire-based research publications.

Table 2.1: Vulture species included in questionnaire-based studies and their conservation status (IUCN, 2022).

Family	Species	Species Common Name	Global Conservation Status	Number of Studies
Accipitridae (Old World Vultures)	*Neophron percnopterus*	Egyptian Vulture	Endangered	30
	Necrosyrtes monachus	Hooded Vulture	Critically Endangered	27
	Gyps africanus	White-backed Vulture	Critically Endangered	23
	Gyps bengalensis	White-rumped Vulture	Critically Endangered	17
	Gyps fulvus	Eurasian Griffon	Least Concern	15
	Gyps indicus	Indian Vulture	Critically Endangered	13
	Aegypius monachus	Cinereous Vulture	Near Threatened	13
	Gypaetus barbatus	Bearded Vulture	Near Threatened	13
	Gyps coprotheres	Cape Griffon	Vulnerable	12
	Trigonoceps occipitalis	White-headed Vulture	Critically Endangered	11
	Gyps tenuirostris	Slender-billed Vulture	Critically Endangered	10
	Torgos tracheliotos	Lappet-faced Vulture	Endangered	10
	Gyps rueppelli	Rüppell's Vulture	Critically Endangered	7
	Gyps himalayensis	Himalayan Griffon	Near Threatened	7
	Sarcogyps calvus	Red-headed Vulture	Critically Endangered	6
	Gypohierax angolensis	Palm-nut Vulture	Least Concern	2
Cathartidae (New World Vulture)	*Vultur gryphus*	Andean Condor	Vulnerable	8
	Coragyps atratus	Black Vulture	Least Concern	4
	Cathartes aura	Turkey Vulture	Least Concern	2
	Gymnogyps californianus	California Condor	Critically Endangered	1
	Cathartes burrovianus	Lesser Yellow-headed Vulture	Least Concern	1
	Sarcoramphus papa	King Vulture	Least Concern	0
	Cathartes melambrotus	Greater Yellow-headed Vulture	Least Concern	0

2.4.4 Questionnaire participants

We investigated the range of stakeholder groups included in questionnaire-based vulture research. Many of the studies had already categorised participants into stakeholder groups. We retained most of these categories but further refined them where appropriate (Table 2.2).

The studies included in this review covered a wide range of important stakeholders relevant to vulture conservation. These groups encompass various sectors, such as local communities, wildlife conservationists, government workers, researchers, and law

enforcement. Additionally, stakeholders from industries potentially impacting vulture populations, such as agriculture, waste management, and tourism, have also been represented in the studies.

The most commonly interviewed groups were farmers (n = 51 studies) and community members in vulture-inhabited areas (n = 48 studies). Other moderately interviewed groups included veterinary practitioners (n = 13 studies), butchers/abattoir staff (n = 10 studies), traditional health practitioners (n = 9 studies) and wildlife traders (n = 8 studies). Several other important stakeholder groups received less attention (Table 2.2). Among these were poachers (n = 4 studies), supplementary feeding site (SFS) management (n = 4 studies), rangers (n = 2 studies), buyers of illegally traded wildlife (n = 1 study) and law enforcement (n = 1 study).

Table 2.2: Stakeholder groups and frequency of questionnaire participation.

Stakeholder groups	Questionnaire count
Farmers	51
Community members	48
Veterinary practitioners	13
Butchers/Abattoir staff	10
Traditional health practitioners	9
Wildlife traders	8
Hunters	6
Tourists at national parks/nature reserves	6
Forestry officials	5
Pharmaceutical services	5
Conservationists	4
Poachers	4
SFS management	4
Students	4
Government workers	3
Teachers	3
Vendors/Traders	3
Agricultural shop owners	2
Land managers/owners	2
Landfill staff	2
Rangers	2
SFS visitors	2
Wildlife experts	2
Wildlife sanctuary/rehabilitation centre staff	2
Zoo visitors	2
Birdwatchers	1
Buyers of illegally traded wildlife	1
Cancer patients	1
Cultural/religious authorities	1
Fishermen	1
Gardeners	1
Law enforcement	1
Manual labourers	1
Ornithologists	1
Pest control products board	1
Pilots	1
Tourist centre staff	1
Village chiefs	1
Zoo staff	1

2.4.5 Questionnaire methods

The review of the literature highlighted a variety of questionnaire methods used across the studies. The most popular method used in 24% of the studies was structured face-to-face interviews. Semi-structured face-to-face interviews followed, accounting for 23%. Another method used was structured self-administered paper questionnaires (4%). Additionally, some studies used mixed methods, such as semi-structured face-to-face interviews combined with key informant interviews (1%) or focus groups (4%), and structured face-to-face interviews with online (1%) or self-administered questionnaires (1%). Telephone interviews were used in 2% of the studies, either on their own or combined with other methods. Postal questionnaires and emailed questionnaires were also used in 2% of studies. Randomised response technique (RRT) was used in 1% of the studies, either with structured face-to-face interviews or combined with self-administered paper questionnaires. A number of studies, 9%, used face-to-face interviews but did not specify the questionnaire structure, and 10% did not specify the questionnaire method or structure at all.

The predominant method for gathering data from the majority of stakeholder groups was face-to-face interviews. Telephone interviews were primarily used to collect information from supplementary feeding site managers and visitors. In one study, zoo staff participated through an online questionnaire (Cuthbert et al., 2007). Lastly, the data collection methods for land managers/owners and ornithologists were not specified in the studies.

2.4.6 Sampling methods

We found various sampling methods were used in the publications. These included purposive sampling, random sampling, snowball sampling, convenience sampling, stratified random sampling, stratified sampling, systematic sampling and opportunistic sampling. At least 25% of the studies used multiple sampling methods when seeking participants.

The most commonly used method was purposive sampling, appearing in 47% of the studies. Random sampling was the next most common method used in the publications (25%). Convenience sampling was featured in 17% of the studies. However, it was reported to introduce sampling bias in some studies (Boshoff et al., 2009; Pfeiffer et al., 2015; Craig et al., 2018; Wahl et al., 2023). Snowball sampling, a non-random technique where existing study participants recruit future participants (Parker et al., 2019), was used in 12% of the studies. Systematic sampling was used in 6% of the studies. Both stratified sampling (4%) and stratified random sampling (3%) were used in a few studies. The final sampling method that was used in these studies was opportunistic sampling, which was used in 3% of studies.

2.4.7 Key questionnaire themes identified across stakeholder groups

We found that the data revealed several recurring themes in questionnaire-based vulture research across the stakeholder groups (Supplementary Information Table S2.3). Common key themes were the public perception of vultures, the utilisation of vultures in traditional medicine and cultural practices, and identifying threats to vultures.

2.4.7.1 The public perception of vultures

We found assessing public perceptions of vultures was a prevalent research objective on a global scale. Farmers and community members in vulture-inhabited areas were frequently interviewed on this topic, with 33 (29%) studies interviewing farmers and 28 (25%) interviewing community members. Additionally, veterinary practitioners (n = 9, 8% of total studies) and butchers/abattoir staff (n = 7, 6% of total studies) were interviewed on this issue, among other stakeholders. A large volume of the studies focussed on the public perception of vultures; however, studies on this issue were lacking among certain stakeholder groups such as tourists (n = 2 studies, 2%), poachers (n = 1 study, 1%), landowners/managers (n = 1 study,

1%) and rangers (n = 1 study, 1%), suggesting potential gaps in the understanding of attitudes towards vultures within these groups.

The perceptions of vultures varied across studies, stakeholder groups, and countries (Figure 2.3). However, several key themes emerged. Farmers often had conflicting views about vultures. Many (13% of studies) perceived them as pests, believing that vultures threaten livestock by attacking animals and consequently threatening their livelihoods. This was mentioned in studies in Argentina, Bolivia, Greece, Spain, Ethiopia, Namibia, South Africa, and the United States of America (USA), demonstrating that this is a widespread negative perception based on a misconception of vulture behaviour. Conversely, studies (18%) in France, Namibia, Nepal and South Africa noted farmers' appreciation for having vultures on their farms. They recognised the invaluable role that vultures play in carcass disposal. These farmers welcomed vultures as natural scavengers that efficiently remove dead livestock at a cost-free rate. Additionally, farmers also mentioned that vultures assist in identifying dead livestock, aiding in the timely removal of carcasses and minimising potential hazards. These contrasting perspectives among farmers highlight the complex relationship between vultures and agricultural practices.

The cultural significance of vultures was highlighted by participants in many of the studies (25%, n = 29), particularly by community members, traditional healers and wildlife traders, across diverse regions. In Asian countries, such as China and India, as well as South America, particularly Chile and Colombia, vultures were perceived as sacred beings and good omens. Within these cultural contexts, vultures were often associated with spiritual entities, representing guardians that facilitate the journey of the departed to the afterlife. This respect for vultures extended to various rituals and ceremonies, especially those where they played symbolic roles in cultural practices and belief systems. Conversely, in many African countries, vultures were often negatively perceived and associated with witchcraft, believed to bring

misfortune. These superstitions instil fear and a strong aversion towards vultures within African communities. Despite these negative perceptions, vultures hold cultural significance through their use in traditional medicine. Traditional healers in Africa and wildlife traders in various regions often use vultures for their perceived medicinal properties, incorporating them into remedies and rituals (Mashele et al., 2021b; Mashele et al., 2021a). However, the exploitation of vultures for these purposes poses a significant threat to their populations, regardless of whether they are viewed positively in this light.

Across the studies (40%, n = 46), there was a general appreciation for vultures and the ecological services they provide. Many participants viewed vultures as providers of essential ecosystem services, such as cleaning the environment, carcass disposal and preventing disease spread, through their scavenging behaviour. In some studies (8%, n = 9), participants explicitly voice their support for vulture conservation efforts, emphasising the importance of preserving these birds for future generations.

Despite the positive sentiments expressed by many participants, negative perceptions of vultures persist in many countries. Particularly in studies that occurred in African countries, but also Costa Rica, various stakeholders described vultures as having an ugly appearance, often using terms like “disgusting”, “repulsive”, “scary” and “odd-looking”. Additionally, vultures were sometimes perceived to spread disease and display aggressive behaviour.

A consistent theme throughout the publications was the importance of collaboration, increased education, and heightened awareness among stakeholders to positively shape perceptions of vultures, and so ensure their conservation.

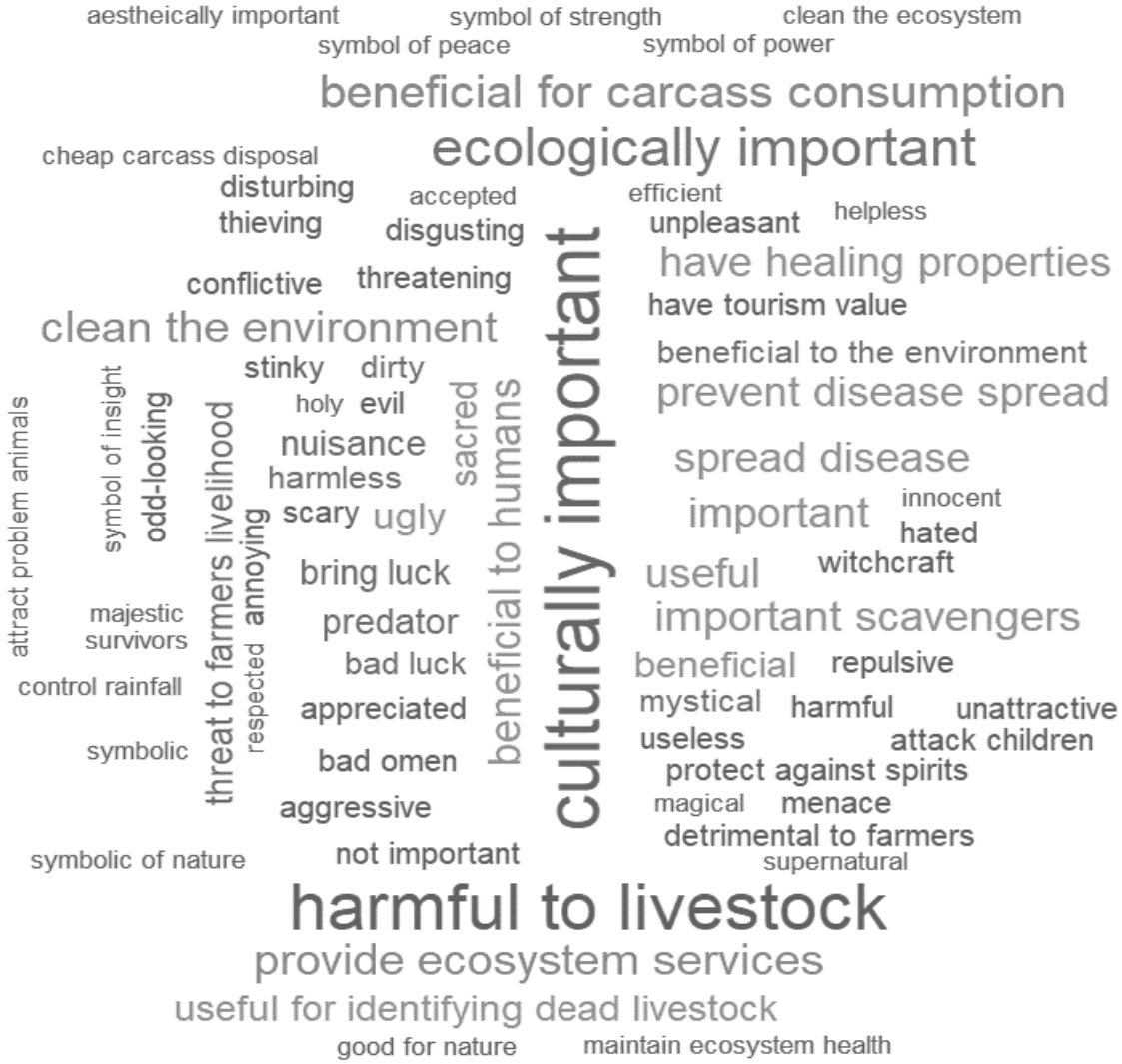


Figure 2.3: A word cloud summary of the public perceptions of vultures. The size of each word represents the frequency with which that perception was expressed in the studies, with larger words indicating more commonly held views.

2.4.7.2 Public knowledge of vultures

We found there was a widespread global acknowledgement among participants regarding the decline in vulture populations, with many noting a decrease in vulture presence in their respective regions. For example, individuals such as community members, butchers/abattoir staff, and veterinary professionals interviewed in Burkina Faso demonstrated a good understanding of the vital ecosystem services provided by vultures and were aware of the

population declines observed (Daboné et al., 2022; Daboné et al., 2023). Similarly, community members and supplementary feeding site managers interviewed in South Africa exhibited awareness of vulture population declines and highlighted the necessity for conservation efforts (Brink et al., 2020b; Brink et al., 2020a). This awareness extended to participants interviewed in Cabo Verde, Ethiopia, Kenya, Namibia, Nigeria, and Zimbabwe.

In various South Asian countries, including India, Nepal, and Pakistan, participants displayed a substantial understanding of vulture population declines, as evidenced by their accurate recognition of the causes and the urgent need for conservation measures. Furthermore, there was widespread support for conservation efforts among these communities, indicating a collective commitment to safeguarding vulture populations. Similarly, hunters interviewed in the USA (Chase & Rabe, 2015) and participants interviewed in Spain (Oliva-Vidal et al., 2022) expressed awareness of population declines and voiced support for conservation initiatives, highlighting a global concern for vulture conservation.

However, it's noteworthy that many questionnaire-based studies did not delve into people's understanding and awareness of vulture population declines and the need for conservation efforts in certain regions, suggesting a potential gap regarding these critical topics. The authors clarified that addressing these gaps through targeted education and awareness initiatives could further bolster conservation endeavours and ensure the long-term viability of vulture populations worldwide.

2.4.7.3 Threats to vultures

We found that the publications discussed various threats facing vultures (Supplementary Information Table S2.3). The most prominent issues mentioned by researchers were intentional and unintentional poisoning (76%, n = 87 studies). This poisoning often results from exposure to non-steroidal anti-inflammatory drugs (NSAIDs) used to treat livestock or from pesticides

and other chemicals deliberately applied to carcasses to target vultures or other scavengers (Otieno et al., 2011; Cuthbert et al., 2014; Aina et al., 2022; Manigandan et al., 2023). Additionally, the lack of food availability (29%, n = 33 studies) (Murn & Anderson, 2008; Mateo-Tomás & Olea, 2010; Ansari, 2015) and habitat loss (31%, n = 35 studies) (Subedi et al., 2018; Oppel et al., 2022; Jha et al., 2023) were frequently highlighted as prominent threats. Another important issue raised was the use of vultures in traditional medicine and cultural practices (28%) (Atuo & O'Connell, 2015; Boakye et al., 2019; Mashele et al., 2021b; Mashele et al., 2021a), which drives poaching and the illegal trade of these birds (Mmahi & Usman, 2020; Muhammad & Mustapha, 2020; Owolabi et al., 2020; Awoyemi et al., 2022; Stara et al., 2022).

2.4.7.4 Land use change and habitat loss

The issue of land use change and habitat loss was frequently studied in Africa, especially regarding the Hooded Vulture (Gbogbo & Awotwe-Pratt, 2008; Odino et al., 2014; Henriques et al., 2018). In addition to habitat loss, vultures were reported to face numerous dangers from human infrastructure. The literature frequently mentioned birds being fatally injured by flying into various energy infrastructure elements, such as wind turbines, and being electrocuted by powerlines. Studies also mentioned vultures colliding with aeroplanes (Hauptfleisch & Avenant, 2016), and being hit by motor vehicles (Daboné et al., 2023).

2.4.7.5 Supplementary feeding site management, carcass availability, and safe carcass provisioning

We found several publications focused on the declining availability of natural food sources for vultures. This was attributed to habitat loss and increased sanitisation regulations enforced worldwide (Dupont et al., 2012; Phuyal et al., 2016; Henriques et al., 2018; Jha et al., 2023;

Piebeng et al., 2023). Farmers and community members in interviews in India (Manigandan et al., 2021) and Nepal (Baral et al., 2005; Dhakal et al., 2022) indicated that a substantial number of livestock carcasses are buried instead of being left in the open, causing limited food availability for vultures. Additionally, the lack of food availability because of domestic dogs (*Canis lupus familiaris*) was studied in Zimbabwe, and interviews were conducted with rural community members. Dogs were said to outcompete vultures in accessing carcasses because of their greater numbers, physical strength and ability to coexist with growing human populations (Butler & du Toit, 2002). This also appeared to be an issue in India, where interviews with community members revealed that dogs and crows (*Corvus splendens, Corvus macrorhynchos*) were often seen feeding on cattle carcasses but not vultures (Ansari, 2015). Aside from a lack of carcass availability, there was a focus in the literature on the safety of available carcasses for vultures. One of the primary concerns is the contamination of carcasses with veterinary drugs such as non-steroidal anti-inflammatory drugs (NSAIDs) (Cuthbert et al., 2007) and antibiotics (Gómez-Ramírez et al., 2018), which can be fatal to vultures if consumed. This contamination is not isolated to veterinary drugs, as lead contamination from ammunition that hunters use was also reported to be a great risk to vultures (Chase & Rabe, 2015).

Supplementary feeding sites (SFSs) play a crucial role in providing safe food sources for vulture populations, as shown by publications from South Africa (Brink et al., 2020b; Brink et al., 2020a). Murn and Anderson (2008) highlighted the positive impact of establishing vulture restaurants on farms, as the presence of SFSs was reported to positively influence vulture feeding, nesting, and breeding activities. The majority of SFS managers interviewed in South Africa were also livestock farmers (Murn & Anderson, 2008; Brink et al., 2020a) who perceived these sites positively because of their role in disposing of livestock carcasses through vulture feeding (Brink et al., 2020a). The SFS managers reportedly assessed carcass suitability based on the absence of veterinary drugs, primarily using carcasses from their properties or

those of neighbours, while avoiding diseased animals. In South Africa, SFSs were estimated to fulfil 83% of vultures' annual food requirements, attracting an average of 72 vultures per feeding event (Brink et al., 2020b). When choosing locations for the feeding sites, managers took various factors into consideration, such as the presence of powerlines, to ensure a safe place for vultures (Brink et al., 2020a).

2.4.7.6 Non-steroidal anti-inflammatory drugs, pesticides and other veterinary drugs

The impacts of vultures consuming carcasses treated with toxic NSAIDs, pesticides, antibiotics, and other agrochemicals were explored in several studies (24%, n = 27). Farmers, veterinary practitioners, agricultural shop owners, community members, conservationists, a pest control products board, pharmaceutical service providers, rangers, students, teachers, wildlife sanctuary staff, rehabilitation centre staff and zoo staff were interviewed regarding the issue of contaminated carcasses (Supplementary Information Table S2.4).

The literature revealed a variety of poisons and chemicals responsible for intentional and unintentional vulture poisoning across multiple countries and continents (Table 2.3). Pesticides and toxic plants used to poison carcasses were most commonly reported in African countries such as South Africa, Namibia, Ghana, Kenya, Niger and Nigeria. Specific pesticides included aldicarb, carbofuran, carbosulfan, glyphosate, strychnine, zinc phosphide, and 2,4-D. Toxic plants like Euphorbia and tobacco, as well as store-bought chemicals, were also identified. In contrast, poisoning carcasses with NSAIDs and antibiotics were more frequently reported in Europe and Asia, with diclofenac reported in India, Nepal and Spain, and antibiotics in Portugal. Carprofen and flunixin meglumine were noted in unspecified European countries.

The majority of poisons and chemicals were reported in studies conducted within the last decade, suggesting an ongoing threat to vultures on many continents (Table 2.3). For example, aldicarb use was reported in interviews conducted in 2019 in South Africa (McKean

et al., 2013; Brink et al., 2021) and in 2015 in Namibia (Santangeli et al., 2017). Carbofuran use was documented in Ghana during a 2016 study (Deikumah, 2020), in Namibia during a 2015 study (Santangeli et al., 2017), and in Kenya (Odino & Ogada, 2021). Glyphosate, zinc phosphide, and 2,4-D were reported in a questionnaire in Kenya between 2007 and 2017 (Odino & Ogada, 2021). Strychnine use was identified in Namibia (2015) (Santangeli et al., 2017), Kenya (2007-2017) (Odino & Ogada, 2021), Argentina, Bolivia (Ballejo et al., 2019), and Cabo Verde (2016) (Freitas et al., 2020). Toxic plants, such as Euphorbia, and store-bought chemicals, were reported in Namibia in 2016 (Craig et al., 2019), and tobacco poisoning was noted in Niger and Nigeria in 2014 (Kret et al., 2018; Stara et al., 2022). NSAIDs were reported in India across multiple questionnaires from 2004 to 2020, and in Nepal in 2004 and 2016. Diclofenac was reported in many studies in India (Cuthbert et al., 2014; Kumar et al., 2016; Brookes et al., 2019; Campbell & Radhika, 2020; Samson & Ramakrishnan, 2020; Manigandan et al., 2021; Jha et al., 2023), Nepal (Baral et al., 2007; Shah et al., 2019), and one study in Spain (Camiña et al., 2018), all mostly occurring in the last decade. Antibiotic-related poisoning was documented in Portugal in 2018 (Gómez-Ramírez et al., 2018).

Table 2.3: Summary of the use of poisons in various countries and the dates of the studies that documented this use. It highlights the geographic distribution and temporal scope of research on vulture poisoning incidents.

Poison		Country	Continent	Study year	Publication Year
Pesticides	Aldicarb	South Africa	Africa	2019	2021
		Namibia	Africa	2015	2017
	Carbofuran	Ghana	Africa	2016	2020
		Namibia	Africa	2015	2017
		Kenya	Africa	Not stated, 2017	2011, 2021
	Glyphosphate	Kenya	Africa	2017	2021
	Strychnine	Namibia	Africa	2015	2017
		Kenya	Africa	2017	2021
		Argentina	South America	Not stated	2019
		Bolivia	South America	Not stated	2019
		Cabo Verde	Africa	2014	2020
	Zinc Phosphide	Kenya	Africa	2017	2021
	2,4-D (phenoxy-carboxylate) acetic acid	Kenya	Africa	2017	2021
NSAIDs & other veterinary drugs	Carprofen	Not stated	Europe	Not stated	2007
	Flunixin meglumine	Not stated	Europe	Not stated	2007
	Diclofenac	India	Asia	2004, Not stated, Not stated, 2020, Not stated, Not stated	2014, 2019, 2016, 2023, 2023, 2019
		Nepal	Asia	2004, 2016	2010, 2019
		Spain	Europe	2014	2018
	Antibiotics	Portugal	Europe	2013	2018
Toxic plant	Euphorbia plants	Namibia	Africa	2016	2019
	Store-bought chemicals	Namibia	Africa	2016	2019
	Tobacco	Niger	Africa	2014	2018
		Nigeria	Africa	2014	2018

2.4.7.7 Unintentional poisoning of vultures

Questionnaire-based research on the unintentional poisoning of vultures often identifies farmer-predator conflict as a primary cause. In various countries, livestock farmers have reported incidents of predators such as domestic dogs, spotted hyenas (*Crocuta crocuta*),

baboons (*Papio ursinus*), black-backed jackals (*Lupulella mesomelas*) (Otieno et al., 2011), tigers (*Panthera tigris*), leopards (*Panthera pardus*) and wild dogs (*Lycaon pictus*) (Samson & Ramakrishnan, 2020) attacking and killing their livestock (Otieno et al., 2011). In response, farmers resort to lacing carcasses with poisons intended for predators, inadvertently leading to vulture fatalities.

In Kenya, this was a commonly researched issue. For example, 21% of Kenyan farmers interviewed in a 2018 study admitted to using poison to control predators, with poison use more common among those whose livestock was killed by predators (Didarali et al., 2022). Carbofuran was readily available in many agricultural shops in the country (Odino & Ogada, 2021) and was the most preferred pesticide by farmers for agricultural practices (Otieno et al., 2011; Odino & Ogada, 2021); however, it was also used as a poison to kill predators that threatened their livestock (Otieno et al., 2011). Community members also used poisons to eliminate "problem animals," kill bees and birds, and poach crocodiles (Odino & Ogada, 2021).

Similarly, in Namibia, 20% of farmers interviewed admitted to using poison to kill predators, and 34% said they would start using poison if predators killed their livestock (Santangeli et al., 2016). This was also admitted to by 36% of farmers in another study. (Craig et al., 2019). Additionally, Namibian farmers revealed that aldicarb, carbofuran, and strychnine were the most commonly used poisons, with the majority (over 80%) placing poisoned baits on their farms, while others contaminated whole carcasses (Santangeli et al., 2017).

In Ethiopia, the use of poison to control predators was reported in interviews by 46% of farmers (Oppel et al., 2022). A small number of interviewees in a 2014 questionnaire in Cabo Verde admitted to using poison to kill domestic dogs, rodents (*Rodentia* spp.), guineafowl (*Numida meleagris*) and ravens (*Corvus corax*) (Freitas et al., 2020). In Albania, interview participants admitted to being aware of poisoning practices in the country, as well as personally poisoning carcasses themselves (Dobrev et al., 2022; Dobrev, 2023).

We found that many studies (19%, n = 22) focused on diclofenac use, revealing varied knowledge about its impact on vultures among different stakeholders. In Nigeria, only 10% of veterinary practitioners interviewed in a survey were aware of the impact of diclofenac on vultures (Aina et al., 2022). Similarly, in Nepal, only 3% of community members interviewed in a 2016 questionnaire were aware of the effects of diclofenac on vultures, and two private veterinary professionals were unaware of the diclofenac ban (Phuyal et al., 2016; Dhakal et al., 2022).

In India, veterinarians admitted to using diclofenac instead of meloxicam because of its lower cost, despite meloxicam not being a known cause of vulture fatalities. The majority of these vets refused to stop using diclofenac (Kumar et al., 2016). Additionally, 79% of cattle owners interviewed in one study were not aware of the effect of diclofenac on vultures (Samson & Ramakarishnan, 2016), although a study conducted in 2019 showed that the majority of Indian farmers were aware of its detrimental effects (Manigandan et al., 2021).

Several (36%) pharmacists interviewed in Spain admitted to selling diclofenac (Camiña et al., 2018). The identified hotspots for diclofenac sales overlapped with the distribution ranges of Cinereous Vultures (*Aegypius monachus*), Egyptian Vultures (*Neophron percnopterus*) and Eurasian Griffon Vultures (*Gyps fulvus*). Only 10% of the pharmacists required a prescription from a veterinarian before selling diclofenac, demonstrating the ease of obtaining it across Spain (Camiña et al., 2018).

2.4.7.8 Intentional poisoning of vultures

When we examined the literature on the persecution of vultures by farmers, trapping, shooting and poisoning were recurring themes. Numerous studies (16%, n = 18) uncovered instances where farmers and poachers had intentionally poisoned vultures. This behaviour was mostly driven by the perceived threat of vulture attacks on livestock. Interestingly, in some of the

reported incidents, participants had not witnessed vulture attacks firsthand (Salom et al., 2021; Oliva-Vidal et al., 2022). Rather, they inferred vultures as the culprits because of their proximity to deceased livestock (Wahl et al., 2023). Farmers commonly reported that younger animals, particularly during birth, were more susceptible to vulture attacks (Salom et al., 2021; Wahl et al., 2023). However, researchers emphasised the need for further investigation into distinguishing actual from perceived vulture attacks (Salom et al., 2021).

In various questionnaires conducted in Argentina, Andean Condors (*Vultur gryphus*) were reported to kill livestock (Arnulphi & Lambertucci, 2017; Ballejo et al., 2019; Salom et al., 2021; Jácome et al., 2022). A significant number of farmers in Spain (Morales-Reyes et al., 2018; Oliva-Vidal et al., 2022) also believed vultures to be a risk to livestock.

In a 2012 Ethiopian survey, the majority of livestock farmers stated that birds of prey were responsible for killing their livestock, and also noted Hooded Vultures and White-backed Vultures commonly killed chickens (Mulualem & Tesfahunegny, 2015). Similarly, farmers in South Africa also claimed livestock losses were because of vultures, and many admitted to killing vultures in retaliation (Boshoff et al., 2009). In the USA, some farmers reported vulture attacks on livestock and stated that killing vultures was the most effective mitigation strategy (Wahl et al., 2023).

2.4.7.9 Sentinel poisoning by poachers

We found that the issue of poachers poisoning the carcasses of animals they have killed to avoid detection by the authorities is another concern that was addressed in the research. This practice, known as sentinel poisoning, was investigated in Nigeria. Interviews revealed that poachers kill vultures to avoid detection and arrest by authorities. They also claimed that hunting on their native land is part of their cultural heritage. Despite acknowledging the illegality of their actions, they showed no intention of stopping (Mmahi & Usman, 2020).

2.4.7.10 Poisoning and poaching to be sold to the illegal vulture trade

The poaching of vultures was reported in Peru, South America. A 2010 survey of wildlife traders revealed that Andean condor body parts and feathers are often sold for various cultural reasons (Table 2.4). Feathers and body parts were reported to be obtained through collecting moulted feathers at nest sites, as well as shooting and poisoning. Some respondents were aware of the illegality of selling condors, and others believed it was legal (Williams et al., 2011).

The literature showed that the poaching of vultures was most prevalent in Africa. Traditional healers in South Africa shed light on the widespread harvesting of vultures from protected areas, communal lands and neighbouring countries such as Lesotho and Mozambique (Mashele et al., 2021b; Mashele et al., 2021a). Poisoning was noted as the most destructive poaching method, with a single poisoning event resulting in multiple vulture fatalities (McKean et al., 2013). A questionnaire survey conducted in Niger in 2014 uncovered the existence of an organised poaching network, where Nigerian poachers spend months harvesting raptors, including vultures, to then bring back to Nigeria to sell. The community members interviewed stated that vultures are killed by shooting, poisoning, and using noose traps. They also collected chicks or eggs from nests (Kret et al., 2018). Poachers in Burkina Faso often kill vultures for personal use but are now also trading them because of the increasing profitability of regional sales (Daboné et al., 2023), making poaching a continentwide threat to vultures.

2.4.7.11 Illegal trade of vultures

We found that the illegal trade of vultures is a concerning practice, mainly observed across Africa, reported on by several questionnaire-based studies (13%, n = 15). In Nigeria, it was found that most illegal wildlife traders were young men who inherited the trade from their parents (Williams et al., 2021). Nigerian wildlife traders reported that the number of stalls

selling vultures at markets had increased, as well as the price of body parts (Saidu & Buij, 2013) and the distances from which the carcasses were gathered to be sold (Muhammad & Mustapha, 2020). Traders often have feathers, heads, entire carcasses (Saidu & Buij, 2013), and live vultures on display (Williams et al., 2021).

The pathways of the illegal vulture trade were investigated in South Africa. The traditional health practitioners interviewed revealed that various vulture species were traded annually, and they had no preference for species. However, White-backed Vultures and Cape Vultures were the most commonly traded species because of their greater availability (McKean et al., 2013). The trade of vultures was fuelled by traditional medicine and cultural practices (Saidu & Buij, 2013; Muhammad & Mustapha, 2020; Mashele et al., 2021a; Mashele et al., 2021b; Stara et al., 2022).

2.4.7.12 The use of vultures in traditional medicine and cultural practices

We found that traditional medicine and cultural practices involving vultures also received considerable attention in questionnaire-based research (32%). Community members (n = 8 studies), traditional health practitioners (n = 6 studies) and wildlife traders (n = 6 studies) were the stakeholder groups most studied in the literature, indicating a strong cultural relationship between traditional healing practices and vultures in rural and tribal communities throughout Africa (Adeola, 1992; Beilis & Esterhuizen, 2005; McKean et al., 2013) and Asia (Jha et al., 2023). Traditional health practitioners were reported to play a significant role in driving demand for vultures by prescribing them for medicinal and belief-based use (McKean et al., 2013). In Lesotho, traditional healers at markets were often observed selling vultures (Beilis & Esterhuizen, 2005). Hooded vultures were reported as commonly used in Nigeria for traditional medicine, religious and/ or cultural beliefs, such as the head of the vulture is said to invoke witches, and farmers use body parts for medicinal purposes in more rural areas (Adeola, 1992).

Various indigenous communities in India described the use of vultures in traditional medicine, superstitious practices and cultural rituals. They also reported the use of vulture body parts as scarecrows to deter birds and wild animals from their agricultural fields (Table 2.4) (Jha et al., 2023). Inherently linked to the issue, yet underrepresented in the questionnaire-based research, were poachers (n = 2 studies) and buyers of illegally traded vultures (n = 1 study).

Table 2.4: Summary of reasons for the use of traditional medicine among different stakeholder groups in various countries, and the specific vulture body parts used for each purpose.

Continent	Country	Traditional medicine/ Cultural practice use	Body parts	Species
Africa	Nigeria	Spiritual healing	Head, feathers, whole carcasses	Hooded Vulture
		Protection against witches	Head, feathers, whole carcasses	Hooded Vulture
		Clairvoyant powers	Head, feathers, whole carcasses	Hooded Vulture
		Cures illnesses	Head, feathers, whole carcasses	Hooded Vulture
			Unspecified	Egyptian Vulture, White-backed Vulture
		Easing birth in women	Head, feathers, whole carcasses	Hooded Vulture
		Stimulates walking in infants	Head, feathers, whole carcasses	Hooded Vulture
		Bring good luck	Head, feathers, whole carcasses	Hooded Vulture
		Success in gambling	Head, feathers, whole carcasses	Hooded Vulture
			Unspecified	Egyptian Vulture, White-backed Vulture
		Success in business ventures	Unspecified	Egyptian Vulture, White-backed Vulture
		Used in witchcraft	Unspecified	Egyptian Vulture, White-backed Vulture
		Clairvoyant powers	Brain, blood, feet, head, heart, intestines	Hooded Vulture, Bearded Vulture, White-backed Vulture, Cape Vulture, White-headed Vulture, Lappet-faced Vulture
	South Africa	Protection against witches	Brain, blood, feet, head, heart, intestines	Hooded Vulture, White-backed Vulture, Cape Vulture, White-headed Vulture, Lappet-faced Vulture
		Good dreams	Brain, blood, feet, head, heart, intestines	Hooded Vulture, White-backed Vulture, Cape Vulture, White-headed Vulture, Lappet-faced Vulture

Africa (continued)		Winning the lottery	Brain, blood, feet, head, heart, intestines	Hooded Vulture, White-backed Vulture, Cape Vulture, White-headed Vulture, Lappet-faced Vulture
		Curing illness	Brain, blood, feet, head, heart, intestines	Hooded Vulture, White-backed Vulture, Cape Vulture, White-headed Vulture, Lappet-faced Vulture
		Curing neurological disorders	Brain, blood, feet, head, heart, intestines	Hooded Vulture, Bearded Vulture, White-backed Vulture, Cape Vulture, White-headed Vulture, Lappet-faced Vulture
		Treating physical diseases	Head, unspecified	Hooded Vulture, White-backed Vulture, White-headed Vulture, Ruppell's Vulture, Lappet-faced Vulture, Egyptian Vulture
	Burkina Faso	Treating mental disorders	Head, unspecified	Hooded Vulture, White-backed Vulture, White-headed Vulture, Ruppell's Vulture, Lappet-faced Vulture, Egyptian Vulture
		Good luck in competitions, contests and gambling	Head, unspecified	Hooded Vulture, White-backed Vulture, White-headed Vulture, Ruppell's Vulture, Lappet-faced Vulture, Egyptian Vulture
		Decorating cultural dress	Head	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture
	Chad	Hunting rituals	Head	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture
		Initiation rituals	Head	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture
		Seeking blessings from ancestors	Head	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture
		Seeking clemency from the sky	Head	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture
		Treating injuries	Legs	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture
		Treating mental disorders	Legs	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture

		Treating infertility	Legs	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture
		Bring good luck	Legs	Lappet-faced Vulture, White-backed Vulture, White-headed Vulture, Hooded Vulture, Egyptian Vulture, European Griffon Vulture
		Decorative purposes	Brain, beak, eyes, feathers, feet, heart, legs, skull, wings	Cape Vulture
	Lesotho	Ceremonial purposes	Brain, beak, eyes, feathers, feet, heart, legs, skull, wings	Cape Vulture
		Various medicinal uses	Brain, beak, eyes, feathers, feet, heart, legs, skull, wings	Cape Vulture
		Rituals	Brain, beak, eyes, feathers, feet, heart, legs, skull, wings	Cape Vulture
		Decorating shamanic wands	Bones,	Andean Condor
South America	Peru	Decorating dream catchers	Feathers,	
		Making bone flutes	Whole carcasses,	
		Making ceremonial pipes	Wings	
		Making lucky charm bracelets		

2.4.8 The economic value of vultures

We found several studies (6%, n = 7) discussed the economic value of vultures. Avian-based tourism in the Pyrenees generates $4.9 million USD annually (García-Jiménez et al., 2021), demonstrating the significant economic potential of vulture tourism. In South Africa, 28% of the SFSs surveyed were equipped with viewing hides (Brink et al., 2020a), highlighting a potential tourism opportunity that can be adopted globally.

2.5. Discussion

2.5.1 Insights from questionnaire-based vulture research

We found studies using questionnaires in vulture research have been instrumental in capturing the perceptions of a diverse range of stakeholders, including livestock farmers, local communities, veterinary practitioners, traditional healers, illegal wildlife traders, and conservationists from 38 countries. This extensive data collection has enabled the identification of regions and stakeholders that require targeted educational outreach and increased awareness of vulture-related issues. The insights gained aid in planning conservation measures tailored to different areas and communities' specific needs and challenges.

Through these questionnaires, awareness of vulture population declines has increased. By involving the public in vulture-related research (Daboné et al., 2019), these surveys and interviews have communicated the urgency of vulture conservation issues to a broader audience, fostering a greater public understanding of these birds' challenges (Deikumah, 2020; Samson & Ramakrishnan, 2020). Moreover, it is hoped that by building positive relationships between researchers and participants, these studies will encourage greater public engagement in conservation efforts, thereby strengthening community support for vulture conservation initiatives (Craig et al., 2019).

2.5.1.1 Temporal trends in questionnaire-based vulture research

The early 2000s saw a notable increase in questionnaire-based vulture studies, which has been pivotal in advancing our understanding of vulture ecology, threats, and conservation needs. A likely catalyst for this surge in research activity was the 'Asian Vulture Crisis' of the mid-1990s, triggered by the widespread use of the veterinary NSAID diclofenac, which is toxic to vultures, leading to catastrophic declines in vulture populations across Asia (Cuthbert et al., 2007). The crisis highlighted the critical ecological role of vultures in carcass disposal and disease prevention, spurring a wave of research and conservation efforts (Oaks & Watson, 2011; Ogada et al., 2012).

Concerns over vulture populations have only grown, with 11 out of the 23 species now endangered or critically endangered (IUCN, 2022). Researchers have called for urgent action, warning of potential continental vulture crises in Africa (Ogada et al., 2016) and the Americas (Santangeli et al., 2022). Despite the increased research efforts, vulture populations continue to decline globally (IUCN, 2022), highlighting the complexity and severity of the challenges they face and the need for more effective conservation strategies.

2.5.1.2 Geographical distribution of vulture questionnaire studies

The global spread of these questionnaire studies has provided a comprehensive perspective on vulture ecology and conservation needs, covering 38 countries across five continents. This extensive geographic coverage has revealed regional trends in vulture threats, conservation needs, and public perceptions, informing targeted conservation strategies for different areas. However, significant gaps remain, particularly in regions with vulture populations that have not been the focus of research efforts.

Regions with high vulture diversity and presence require closer attention (Supplementary Information Table S2.2). Conducting research in these areas can provide

unprecedented insights into local perspectives on vulture coexistence and the factors driving vulture declines, enabling the development of targeted conservation initiatives (Prakash et al., 2003; Kumar et al., 2016). Engaging local communities and stakeholders in these regions and creating awareness can foster collaboration and public support for vulture conservation (Cortés-Avizanda et al., 2018).

2.5.1.3 Research attention across vulture species

We found the publications covered a wide range of vulture species, with 21 out of the 23 (91.3%) vulture species worldwide being the subject of questionnaire studies. This broad scope highlighted the in-depth examination of vulture populations on a global scale. However, there remains a need for further research, particularly on vulnerable, endangered and critically endangered species that have not received as much focus (Table 2.1). These species require urgent intervention to prevent further decline. Our analyses revealed a relationship between the global conservation status and the number of studies, with more threatened species receiving more research attention. Critically endangered and endangered species understandably attracted more research attention because of their poor conservation statuses. Conversely, species classified as “Least Concern” received less research attention, perhaps because of the prioritisation of limited resources towards endangered or critically endangered species.

Studies of species in South America are particularly lacking. Despite the comparatively lower threat levels among New World vultures compared with Old World vultures, it remains imperative to allocate research resources to this region. New World vultures play vital ecological roles in their respective ecosystems, and so understanding the risks facing these species is essential for implementing effective conservation measures and avoiding future population declines (Santangeli et al., 2022). Notably, the King Vulture and Greater Yellow-headed Vulture have received no research attention in questionnaire studies. While listed as

least concern on the IUCN Red List of Threatened Species (IUCN, 2022), these species are important nonetheless and require investigation (Haenn et al., 2014; Santangeli et al., 2022). By addressing these gaps in knowledge and expanding the scope of research to include understudied species, we can enhance our understanding of vultures and improve conservation outcomes for all vulture species.

2.5.1.4 Questionnaire participants

We found that the studies have involved a wide range of stakeholder groups, deepening the understanding of complex interactions between vultures and humans. This wide-ranging representation ensures that various perspectives and challenges in vulture conservation efforts are thoroughly considered. Livestock farmers highlighted the challenges of livestock predation and carcass disposal, while traditional health practitioners, poachers, and wildlife traders provided insights into illegal activities and socio-cultural dynamics affecting vulture conservation, particularly in Africa. Community members revealed public perceptions of vultures from various regions worldwide, shedding light on varying levels of awareness and attitudes towards vulture conservation.

Veterinary practitioners provided crucial information on the availability of drugs harmful to vultures, such as diclofenac. Similarly, managers of supplementary feeding sites offered insights into the safe provisioning of carcasses to vultures, ensuring a stable food supply while minimising the risk of poisoning.

Despite the broad range of stakeholders included in these studies, several key groups remain underrepresented, limiting the depth of insights gained. Law enforcement officials and government representatives, whose perspectives are crucial for understanding policy-related challenges and enforcement of conservation laws (Niraj et al., 2012; Singh et al., 2024), were involved in only a few studies. Similarly, ornithologists and conservationists, who possess

specialised knowledge of vulture biology and conservation strategies (Prakash et al., 2003; Yee et al., 2021), were underrepresented, with few studies including their insights. Tourist centre staff, included in just one study, have the potential to provide valuable information on eco-tourism's role in raising awareness and generating support for vulture conservation (Hovardas & Stamou, 2006). Additionally, rangers and forestry officials, key players in managing protected areas and monitoring wildlife, were seldom consulted, yet their experiences are vital for understanding on-the-ground conservation challenges (Kumar et al., 2016; Cortés-Avizanda et al., 2018; Campbell & Radhika, 2020). Village chiefs and cultural or religious authorities, who hold significant influence over rural and tribal communities, were also underrepresented despite their potential to affect local conservation practices and attitudes. By expanding the inclusion of these underrepresented groups, future research can achieve a more comprehensive understanding of the diverse factors influencing vulture conservation and enhance the effectiveness of conservation strategies.

Various important stakeholders were not represented in the literature. With their extensive networks and expertise, conservation non-government organisations could provide valuable perspectives on effective conservation strategies, public outreach, and funding opportunities (Niraj et al., 2012). Game reserve managers, who oversee critical vulture habitats, could offer practical solutions for mitigating threats such as poisoning and habitat destruction, and share insights into habitat management practices. Tour operators and field guides, pivotal in ecotourism (Yamada, 2011), could shed light on the role of tourism in raising awareness and financial support for vulture conservation (Hughes & Ballantyne, 2001), as well as provide detailed observations on vulture behaviour and interactions. Including these stakeholders in future research would enhance our understanding of vultures' multifaceted challenges and help develop more robust and effective conservation strategies.

2.5.2 Questionnaire methods

Despite their resource intensity (Salazar, 1990), we found face-to-face interviews were the most commonly used method for interviewing diverse stakeholder groups, allowing for comprehensive data collection. This approach facilitated direct interaction between the interviewer and respondent, allowing for in-depth exploration of topics and clarification of responses. The interviews allowed the participants to articulate their thoughts and perceptions, and were ideal for understanding complex issues like vulture conservation. Face-to-face interviews are particularly advantageous when engaging stakeholders in tribal communities or rural areas, where access to the Internet may be limited and online questionnaires less effective (Erdiaw-Kwasie & Alam, 2016). In these contexts, direct interaction can build trust and enable deeper exploration of perspectives and challenges, enhancing the reliability of the data collected (Punch, 2013; Muthanna, 2019). However, researchers should remain mindful of inadvertently influencing participants' responses through social desirability bias (Salazar, 1990), especially when discussing sensitive topics such as cultural beliefs or involvement in illegal activities (Pfeiffer et al., 2015; Craig et al., 2019; Salom et al., 2021; Jácome et al., 2022; Jha et al., 2023).

Telephone interviews, used to interview supplementary feeding site managers and visitors, offered the advantage of convenience, allowing for data collection without the need for face-to-face interaction. This was particularly beneficial for reaching geographically dispersed individuals (Brink et al., 2020b; Brink et al., 2020a). However, telephone interviews possibly limited the depth of responses compared with face-to-face interviews, as visual cues and opportunities for the researcher to gain the participants' trust may have been reduced.

The questionnaire methods used in studies surveying and interviewing landowners/managers and ornithologists were not specified in the literature, limiting the ability to evaluate the appropriateness and effectiveness of the data collection methods. Clear

reporting of survey and interview methods is essential for transparency and reproducibility in research studies, enabling readers to assess the validity and reliability of the findings.

2.5.3 Sampling methods

Many different sampling methods were employed across the vulture research studies, each with its own advantages and limitations. The suitability of these methods depends on the study objectives and target participants. Purposive sampling was the most commonly used method. It involves a targeted selection of participants based on characteristics required for the study, allowing the researchers to efficiently collect data that were directly aligned with the study objectives (Sirakaya-Turk & Uysal, 2011). However, it sometimes can lead to potential bias (Boschoff, 1980; Brookes et al., 2019; Yee et al., 2021) and a lack of generalisability in the findings (Sánchez-Pedraza et al., 2012; Brookes et al., 2019; Brink et al., 2020a; Daboné et al., 2022).

Random sampling was useful in reducing participant selection bias and increasing the sample's representativeness (Khadka & Mandal, 2013; Williams et al., 2021). However, it occasionally led to interviewing participants who lacked relevant knowledge or experience of the research topic (Shumsher & Timilsina, 2013; Stara et al., 2022), hindering the collection of meaningful insights.

Convenience sampling, a non-random sampling method where participants are chosen based on their easy accessibility and proximity to the researcher (Scholtz, 2021), was useful for quickly gathering data from readily available participants (Baral et al., 2005; Becker et al., 2010). However, it introduced sampling bias in some studies (Boshoff et al., 2009; Pfeiffer et al., 2015; Craig et al., 2018; Wahl et al., 2023) and should be used cautiously in future studies (Craig et al., 2018).

Snowball sampling is useful for surveying hard-to-reach populations, like those involved in illegal activities, such as persecuting or poisoning vultures (Salom et al., 2021; Jácome et al., 2022; Wahl et al., 2023), poaching (Mmahi & Usman, 2020), trading vultures (Awoyemi et al., 2022), and using vultures in traditional medicine (Henriques et al., 2018; Mashele et al., 2021b; Mashele et al., 2021a; Jha et al., 2023; Manqele et al., 2023), as the initial participants referred the researchers to others working within their network. However, it meant that the researchers had limited control over the participants, as they interviewed people based on referral only who may have shared similar characteristics or opinions. Future efforts should ensure diversity within the sample.

Systematic sampling involves following a systematic and predetermined pattern for participant selection. This method was useful when seeking a representative sample from a large population, minimising bias and increasing the likelihood of capturing diverse perspectives (Hovardas & Poirazidis, 2006; Craig et al., 2019), however, similar to random sampling, it may have hindered the collection of meaningful data.

Stratified and random stratified sampling both involve dividing the target population into distinct subgroups or strata based on certain characteristics, and aim to ensure that each subgroup is represented in the sample. However, they differ in how participants are selected within each stratum. In stratified sampling, the researchers purposefully selected participants from each subgroup based on specific criteria, whereas stratified random sampling involved participants being randomly selected from each subgroup (Brewer, 1999). The advantage of these methods is that the sample accurately reflects the diversity within the population; however, it can be difficult to implement without clear criteria for dividing the population into strata (Odino & Ogada, 2021).

Opportunistic sampling takes advantage of spontaneous opportunities to collect data, which can be useful in field research settings; however, it can cause bias in participant selection

as it relies on available opportunities, and may overlook important subgroups, limiting the generalisability of the findings (Santangeli et al., 2017).

For future questionnaires, researchers should carefully consider the target population's characteristics and select sampling methods accordingly, prioritising random or stratified sampling for representative samples and supplementing with purposive or snowball sampling for specialised or hidden populations. Transparent and detailed reporting of methods is essential for ensuring reproducibility and validity of findings.

2.5.4 Global threats to vultures

We found questionnaire-based vulture research uncovered various themes among the stakeholder groups, shedding light on the public perceptions, cultural significance and the threats these birds face on a global scale. Farmers' perceptions, ranging from viewing them as pests to appreciating their ecological importance, highlight the complex relationship between human actions and wildlife conservation. Similarly, the deep-rooted cultural beliefs surrounding vultures highlight the complex obstacles in the way of conservation efforts. This emphasises the need for a delicate approach to facilitate shifts in societal attitudes towards vultures through educational outreach (Ramos, 2018). Efforts should be particularly focused on Africa, where traditional medicine practices were found to be the most prevalent. Targeted educational outreach initiatives should be employed to promote understanding and change of attitudes towards vultures. There were limited studies of poachers and buyers of illegally traded wildlife regarding the use of vultures in traditional medicine and cultural practices, identifying a crucial gap in the knowledge. Future research should aim to assess whether cultural practices that threaten vultures exist in other African countries, and to interview poachers and buyers of illegally traded wildlife on traditional medicine and cultural practices. This investigation will provide insights into the broader scope of cultural impacts on vulture populations, enabling the

design of more targeted and effective conservation strategies (Deikumah, 2020). Encouragingly, there was a consistent recognition of decreasing vulture populations across Africa, reflecting a promising sign of increasing awareness and support for vulture conservation efforts.

The perceptions of vultures were diverse and multifaceted, shaped by cultural, social, and ecological contexts. While farmers' conflicting views highlight the complexities of human-wildlife interactions in agricultural landscapes, the cultural significance of vultures underscored their importance in spiritual and traditional practices across different regions. Despite facing negative stereotypes and misconceptions, vultures are valued for their crucial ecological roles in maintaining ecosystem health. However, addressing negative perceptions and promoting appreciation for vultures remains essential for their conservation. The prevailing theme throughout the publications was the need for collaboration, increased education, and heightened awareness among stakeholders to positively shape perceptions of vultures and ensure their conservation.

We found the poisoning of vultures by poachers is another issue deeply rooted in cultural traditions and is a critical threat to vulture populations (Murn & Botha, 2018). To deter this, conservation efforts should focus on strengthening law enforcement and developing stringent policies against wildlife poaching (Didarali et al., 2022). Education and outreach programmes can help shift cultural practices towards more sustainable methods. Engaging communities in conservation initiatives and offering alternative livelihoods can reduce reliance on poaching (Cooney et al., 2017). Future research should explore the cultural dimensions of poaching and assess the effectiveness of various deterrent strategies.

The intentional poisoning of vultures by livestock farmers is a widespread issue that poses a significant threat to vulture populations. One poisoning incident can cause hundreds of fatalities (Murn & Botha, 2018). Educating farmers on vulture behaviour, correcting

misconceptions, and creating awareness of the importance of vultures are key to conserving these birds (Duriez et al., 2019). Future research should focus on accurately identifying the causes of livestock deaths, sharing this information with farmers, and developing non-lethal predator control methods.

Underlying these issues is the critical need to control the availability and use of poisons such as NSAIDs and pesticides (Gore et al., 2020). Research has shown how easily accessible these lethal substances are without a permit or prescription (Camiña et al., 2018). Strict regulations and control of these chemicals are essential to mitigate their impact on wildlife (Gore et al., 2020). Conservation efforts should prioritise promoting the responsible use of pesticides and veterinary drugs, ensuring that safe alternatives are available and accessible.

Land use change and habitat were issues frequently discussed in the literature and pose significant threats to vulture populations globally. As human settlements expand, vultures face the effects of habitat change and loss (Ogada et al., 2012), forcing them to coexist with humans in both rural and urban areas. These factors create a challenging environment for vultures, where habitat loss because of human encroachment, along with the associated risks from infrastructure such as wind turbines causing fatal collisions and powerlines causing electrocutions and collisions, contribute to their declining numbers (Zuberogoitia et al., 2008; Reynolds et al., 2019). Effective conservation strategies must address these multifaceted threats to ensure the survival of vultures.

One promising conservation strategy is the establishment of Vulture Safe Zones. These zones involve collaboration with landowners to reduce threats to vultures on their properties (Kane et al., 2022; National Vulture Task Force, 2022). Measures include fitting electricity pylons with safeguards to prevent electrocutions and collisions, modifying water reservoirs to prevent drownings, and protecting breeding sites from disturbances. Supplementary food is provided at vulture restaurants, free from lead and other contaminants. Additionally, poisons

are avoided, and lead-free ammunition is used for culling (National Vulture Task Force, 2022). However, implementing Vulture Safe Zones requires substantial effort due to the extensive ranges of vultures. Establishing these zones involves significant logistical challenges, as they must be much larger than current protected areas and necessitate broad conservation activities beyond existing boundaries (Kane et al., 2022).

Future research should delve further into the impact of supplementary feeding sites in creating a safe food source for vultures and evaluate their effectiveness in reducing poisoning events. It has already been estimated that supplementary feeding sites in South Africa provide 83% of vultures' annual food requirements, demonstrating the significant ecological value of supplementary feeding sites when carcasses are provisioned safely. If employed globally, these feeding sites could play a major role in preventing poisoning events (Brink et al., 2020b). Education campaigns aimed at farmers, pharmacists, veterinary practitioners, and agricultural store owners can raise awareness of the ecological consequences of chemical misuse and promote safer practices (Safford et al., 2019). By addressing the root cause of poisoning, and establishing more Vulture Safe Zones, we can significantly reduce threats to vulture populations.

2.5.5 Incentivising vulture conservation

Highlighting the economic value of vultures can significantly aid in their conservation. Avian-based tourism, such as in the Pyrenees (García-Jiménez et al., 2021), generates substantial revenue and offers a promising avenue for local economic development. SFSs with viewing hides present a potential tourism opportunity that can be adopted globally (Brink et al., 2020a), and allow stakeholders to generate additional income. Promoting vulture tourism, through activities like guided tours and observation hides can incentivise local communities to support vulture conservation. Future efforts should focus on collaborating and developing tourism

opportunities with various stakeholders, ensuring they are beneficial to both vultures and local economies. This approach can foster positive attitudes towards vultures and highlight their importance, therefore garnering broader support for their conservation (Sekercioglu, 2003; Patricia et al., 2021).

2.5.6 Conclusions

We found the use of questionnaire studies in vulture research was shown to be valuable in gathering insights into the perceptions, experiences, thoughts and concerns of important stakeholders in vulture conservation. Understanding how different groups view vultures can inform outreach and education efforts aimed at fostering positive attitudes and reducing negative interactions. The questionnaires identified important cultural beliefs and practices that impact vulture populations worldwide. This information is vital for designing culturally sensitive conservation strategies relevant to the different local traditions. Additionally, involving the public in surveys and interviews fosters community engagement and ownership of conservation initiatives, which is essential for long-term success. Future research should expand questionnaire studies to other countries, and focus research efforts on vulnerable, endangered and critically endangered vulture species, while addressing public concerns such as livestock attacks to inform targeted conservation efforts. Education initiatives should be prioritised to raise awareness about the ecological importance of vultures and promote their conservation among the general public.

2.6 Acknowledgements

We are grateful to the University of KwaZulu-Natal (ZA) and the National Research Foundation (ZA, grant 98404) for funding. We are also grateful to the Rufford Foundation for its financial support.

2.7 References

Adeola, M. O. (1992). Importance of wild animals and their parts in the culture, religious festivals, and traditional medicine, of Nigeria. *Environmental Conservation, 19*(2), 125-134.

Aina, S., Omeje, N., Onoja, J., David, D., Awoniyi, M., & Azugo, S. (2022). A multivariate analysis of veterinary preferences for NSAIDs in Nigeria. *International Journal of Veterinary Science Research*, *8*(2), 34-38.

Ansari, N. A. (2015). Status and distribution of Vultures in Gautam Budh Nagar District, Uttar Pradesh, India. *International Journal of Advanced Research*, *3*(5), 506-511.

Arnulphi, C., & Lambertucci, V. B., Borghi, S. A., Carlos E. (2017). Education can improve the negative perception of a threatened long-lived scavenging bird, the Andean condor. *PLoS One*, *12*(9), e0185278. https://doi.org/10.1371/journal.pone.0185278

Atuo, F. A., & O'Connell T. J. (2015). An assessment of socio-economic drivers of avian body parts trade in West African rainforests. *Biological Conservation, 191*, 614-622.

Awoyemi, S. M., Thomas-Walters, L., Anthony, B. P., Vyas, D., Buij, R., & Amusa, T. O. (2022). Culture and the illegal trade in vultures in southwestern Nigeria: conundrums and recommendations. *Vulture News, 83*, 18-31.

Ballejo, F., Grilli, M. G., & Lambertucci, S. A. (2019). A long and troublesome journey: People's perceptions and attitudes along the migratory path of a scavenger bird. *Ethnobiology and Conservation*, *8*, 13. https://doi.org/10.15451/ec2019-10-8.13-1-13

Baral, N., & Gautam, R. (2007). Socio-economic perspectives on the conservation of Critically Endangered vultures in South Asia: an empirical study from Nepal. *Bird Conservation International*, *17*(2), 131-139.

Baral, N., Gautam, R., & Tamang, B. (2005). Population status and breeding ecology of White-rumped Vulture *Gyps bengalensis* in Rampur Valley, Nepal. *Forktail, 21*, 87.

Baral, N., Gautam, R., Timilsina, N., & Bhat, M. G. (2007). Conservation implications of contingent valuation of critically endangered white-rumped vulture *Gyps bengalensis* in South Asia. *International Journal of Biodiversity Science and Management*, *3*(3), 145-156.

Basak, S. M., Hossain, M. S., O'Mahony, D. T., Okarma, H., Widera, E., & Wierzbowska, I. A. (2022). Public perceptions and attitudes toward urban wildlife encounters–A decade of change. *Science of the Total Environment, 834*, 155603. https://doi.org/10.1016/j.scitotenv.2022.155603

Becker, N., Choresh, Y., Bahat, O., & Inbar, M. (2010). Cost benefit analysis of conservation efforts to preserve an endangered species: The Griffon Vulture (*Gyps fulvus*) in Israel. *Journal of Bioeconomics, 12*, 55-70.

Beilis, N., & Esterhuizen, J. (2005). The potential impact on Cape Griffon *Gyps coprotheres* populations due to the trade in traditional medicine in Maseru, Lesotho. *Vulture News, 53*, 15-19.

Bird, D. K. (2009). The use of questionnaires for acquiring information on public perception of natural hazards and risk mitigation–a review of current knowledge and practice. *Natural Hazards and Earth System Sciences*, *9*(4), 1307-1325.

Boakye, M. K., Wiafe, E. D., & Ziekah, M. Y. (2019). Ethnomedicinal use of vultures by traditional medicinal practitioners in Ghana. *Ostrich*, *90*(2), 111-118.

Boschoff, A. (1980). Some socio-economic aspects of a bird of prey questionaire survey. *South African Journal of Wildlife Research*, *10*(2), 71-81.

Boshoff, A., Barkhuysen, A., Brown, G., & Michael, M. (2009). Evidence of partial migratory behaviour by the Cape Griffon *Gyps coprotheres*. *Ostrich*, *80*(3), 129-133.

Brewer, K. (1999). Design-based or prediction-based inference? Stratified random vs stratified balanced sampling. *International Statistical Review*, *67*(1), 35-47.

Brink, C. W., Santangeli, A., Amar, A., Wolter, K., Tate, G., Krüger, S., Tucker, A. S., & Thomson, R. L. (2020a). Perceptions of vulture supplementary feeding site managers and potential hidden risks to avian scavengers. *Conservation Science and Practice*, *2*(8), e237. https://doi.org/10.1111/csp2.237

Brink, C. W., Santangeli, A., Amar, A., Wolter, K., Tate, G., Krüger, S., Tucker, A. S., & Thomson, R. L. (2020b). Quantifying the spatial distribution and trends of supplementary feeding sites in South Africa and their potential contribution to vulture energetic requirements. *Animal Conservation*, *23*(5), 491-501.

Brink, C. W., Thomson, R. L., Amar, A., Girardello, M., & Santangeli, A. (2021). Prevalence and drivers of poison use by South African commercial farmers and perceptions of alternative livestock protection measures. *Ambio*, *50*, 1211-1221.

Brookes, V. J., Gill, G. S., Singh, B. B., Sandhu, B. S., Dhand, N. K., Aulakh, R. S., & Ward, M. P. (2019). Challenges to human rabies elimination highlighted following a rabies outbreak in bovines and a human in Punjab, India. *Zoonoses and Public Health*, *66*(3), 325-336.

Bulmer, M. (2004). Sage Benchmarks in Social Science Research Methods. In Bulmer, M. (Ed.), *Questionnaires*, (1st ed., pp. 354). Sage Publications, London.

Butler, J., & du Toit, J. T. (2002). Diet of free-ranging domestic dogs (*Canis familiaris*) in rural Zimbabwe: implications for wild scavengers on the periphery of wildlife reserves. *Animal Conservation*, *5*, 29-37.

Camiña, A., Aguilera, J., Sarrazin, F., & Duriez, O. (2018). Potential exposure to diclofenac in Spain of European vultures. *Vulture News*, *75*, 1-20.

Campbell, M. O., & Radhika, J. (2020). Vultures, their population status and some ecological aspects in an Indian stronghold. *Notulae Scientia Biologicae*, *12*(1), 124-142.

Chase, L., & Rabe, M. J. (2015). Reducing lead on the landscape: anticipating hunter behavior in absence of a free nonlead ammunition program. *PLoS One*, *10*(6), e0128355. https://doi.org/10.1371/journal.pone.0128355

Cooney, R., Roe, D., Dublin, H., Phelps, J., Wilkie, D., Keane, A., Travers, H., Skinner, D., Challender, D. W., & Allan, J. R. (2017). From poachers to protectors: engaging local communities in solutions to illegal wildlife trade. *Conservation Letters*, *10*(3), 367-374.

Cortés-Avizanda, A., Martín-López, B., Ceballos, O., & Pereira, H. M. (2018). Stakeholders perceptions of the endangered Egyptian vulture: Insights for conservation. *Biological Conservation*, *218*, 173-180.

Craig, C. A., Thomson, R. L., Girardello, M., & Santangeli, A. (2019). The drivers and extent of poison use by Namibia's communal farmers: Implications for averting the African vulture crisis. *Ambio*, *48*, 913-922.

Craig, C. A., Thomson, R. L., & Santangeli, A. (2018). Communal farmers of Namibia appreciate vultures and the ecosystem services they provide. *Ostrich, 89*(3), 211-220.

Cuthbert, R., Parry-Jones, J., Green, R. E., & Pain, D. J. (2007). NSAIDs and scavenging birds: potential impacts beyond Asia's critically endangered vultures. *Biology Letters, 3*(1), 91-94.

Cuthbert, R. J., Taggart, M. A., Prakash, V., Chakraborty, S. S., Deori, P., Galligan, T., Kulkarni, M., Ranade, S., Saini, M., & Sharma, A. K. (2014). Avian scavengers and the threat from veterinary pharmaceuticals. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1656), 20130574. http://dx.doi.org/10.1098/rstb.2013.0574

Daboné, C., Buij, R., Oueda, A., Adjakpa, J. B., Guenda, W., & Weesie, P. D. (2019). Impact of human activities on the reproduction of Hooded Vultures *Necrosyrtes monachus* in Burkina Faso. *Ostrich*, *90*(1), 53-61.

Daboné, C., Ouéda, A., Thompson, L. J., Adjakpa, J. B., & Weesie, P. D. (2022). Local perceptions and sociocultural value of Hooded Vultures *Necrosyrtes monachus* in Burkina Faso, West Africa. *Ostrich*, *93*(4), 233-247.

Daboné, C., Ouéda, A., Thompson, L. J., Adjakpa, J. B., & Weesie, P. D. (2023). Trade in vulture parts in West Africa: Burkina Faso may be one of the main sources of vulture carcasses. *Bird Conservation International*, *33*, e8. https://doi.org/10.1017/S095927092100054X

Deikumah, J. P. (2020). Vulture declines, threats and conservation: the attitude of the indigenous Ghanaian. *Bird Conservation International*, *30*(1), 103-116.

Dhakal, H., Sharma, H. P., McClure, C. J., Virani, M., Rolek, B. W., Pradhan, N. M. B., & Bhusal, K. P. (2022). Vulture distribution and people's perception of vultures in Pokhara Valley, Nepal. *Ecology and Evolution*, *12*(1), e8528. https://doi.org/10.1002/ece3.8528

Didarali, Z., Kuiper, T., Brink, C. W., Buij, R., Virani, M. Z., Reson, E. O., & Santangeli, A. (2022). Awareness of environmental legislation as a deterrent for wildlife crime: A case with Masaai pastoralists, poison use and the Kenya Wildlife Act. *Ambio*, *51*(7), 1632-1642.

Dobrev, V. (2023). First signs of stabilization of the Egyptian Vulture population in the Balkans. *Vulture News*, *83*(1), 14-23.

Dobrev, V., Topi, M., Hallmann, B., Dobrev, D., Arkumarev, V., Saravia-Mullin, V., Bounas, A., Pappaionnou, H., Bino, T., & Duro, K. (2022). Status and Threats for the Egyptian Vulture *Neophron percnopterus* (Linnaeus, 1758) in Albania. *Acta Zoologica Bulgaria*, 11-18.

Dupont, H., Mihoub, J. B., Bobbé, S., & Sarrazin, F. (2012). Modelling carcass disposal practices: implications for the management of an ecological service provided by vultures. *Journal of Applied Ecology*, *49*(2), 404-411.

Duriez, O., Descaves, S., Gallais, R., Neouze, R., Fluhr, J., & Decante, F. (2019). Vultures attacking livestock: a problem of vulture behavioural change or farmers' perception? *Bird Conservation International*, *29*(3), 437-453.

Erdiaw-Kwasie, M. O., & Alam, K. (2016). Towards understanding digital divide in rural partnerships and development: A framework and evidence from rural Australia. *Journal of Rural Studies*, *43*, 214-224.

Freitas, R., Monteiro, C., Rodrigues, I., Tavares, A., Monteiro, G., Lopez, P., Martins, S., Ferreira, J., Lima, L., & Tavares, J. P. (2020). Cabo Verde Egyptian Vulture *Neophron percnopterus* on the brink: community perceptions, inferences and facts of an extreme population crash. *Bird Conservation International*, *30*(2), 289-307.

García-Jiménez, R., Morales-Reyes, Z., Pérez-García, J. M., & Margalida, A. (2021). Economic valuation of non-material contributions to people provided by avian scavengers: Harmonizing conservation and wildlife-based tourism. *Ecological Economics*, *187*, 107088. https://doi.org/10.1016/j.ecolecon.2021.107088

Gbogbo, F., & Awotwe-Pratt, V. (2008). Waste management and Hooded vultures on the Legon campus of the University of Ghana in Accra, Ghana, West Africa. *Vulture News*, *58*, 16-22.

Gómez-Ramírez, P., Jiménez-Montalbán, P., Delgado, D., Martínez-López, E., María-Mojica, P., Godino, A., & García-Fernández, A. (2018). Development of a QuEChERS method for simultaneous analysis of antibiotics in carcasses for supplementary feeding of endangered vultures. *Science of the Total Environment*, *626*, 319-327.

Gore, M. L., Hübschle, A., Botha, A. J., Coverdale, B. M., Garbett, R., Harrell, R. M., Krüger, S. C., Mullinax, J. M., Olson, L. J., & Ottinger, M. A. (2020). A conservation criminology-based desk assessment of vulture poisoning in the Great Limpopo Transfrontier Conservation Area. *Global Ecology and Conservation*, *23*, e01076. https://doi.org/10.1016/j.gecco.2020.e01076

Haenn, N., Schmook, B., Reyes, Y. M., & Calmé, S. (2014). A cultural consensus regarding the king vulture?: Preliminary findings and their application to Mexican conservation. *Ethnobiology and Conservation*, *3*, 1.

Hauptfleisch, M. L., & Avenant, N. L. (2016). Actual and perceived collision risk for bird strikes at Namibian airports. *Ostrich*, *87*(2), 161-171.

Henriques, M., Granadeiro, J. P., Monteiro, H., Nuno, A., Lecoq, M., Cardoso, P., Regalla, A., & Catry, P. (2018). Not in wilderness: African vulture strongholds remain in areas with high human density. *PLoS One*, *13*(1), e0190594. https://doi.org/10.1371/journal.pone.0190594

Hovardas, T., & Poirazidis, K. (2006). Evaluation of the environmentalist dimension of ecotourism at the Dadia Forest Reserve (Greece). *Environmental Management*, *38*, 810-822.

Hovardas, T., & Stamou, G. P. (2006). Structural and narrative reconstruction of rural residents' representations of 'nature','wildlife', and 'landscape'. *Biodiversity & Conservation*, *15*, 1745-1770.

Hughes, K., & Ballantyne, R. (2001). Interpretation in ecotourism settings: investigating tour guides' perceptions of their role, responsibilities and training needs. *Journal of Tourism Studies*, *12*(2), 2-9.

IUCN. (2022). *Vultures,* IUCN Red List. https://www.iucnredlist.org/search?query=vulture&searchType=species

Ives, A. M., Brenn-White, M., Buckley, J. Y., Kendall, C. J., Wilton, S., & Deem, S. L. (2022). A global review of causes of morbidity and mortality in free-living vultures. *EcoHealth*, *19*(1), 40-54.

Jácome, N. L., Abarzua, G., Astore, V., & Estrada Pacheco, R. (2022). Mass poisonings of the Vulnerable Andean condor prompt national strategy against the use of toxic baits in Argentina. *Ethnobiology and Conservation*, *11*, 14.

Jha, R., Jha, K. K., & Kanaujia, A. (2023). Humans and Vultures: Sociocultural and Conservation Perspective in Northern India. *Human Ecology*, *51*(1), 107-118.

Kane, A., Monadjem, A., Aschenborn, H. O., Bildstein, K., Botha, A., Bracebridge, C., Buechley, E. R., Buij, R., Davies, J. P., & Diekmann, M. (2022). Understanding continent-wide variation in vulture ranging behavior to assess feasibility of Vulture Safe Zones in Africa: Challenges and possibilities. *Biological Conservation*, *268*, 109516. https://doi.org/10.1016/j.biocon.2022.109516

Khadka, K. K., & Mandal, R. K. (2013). Understanding the efficacy of diclofenac use-ban and its aftermath effect on *Gyps* vulture in Koshi Tappu Wildlife Reserve, Nepal. *Journal of Entomology and Zoology Studies*, *1*, 20-22.

Kret, E., Rabeil, T., Muhammad, S., Shiiwua, M., Hall, P., Arkumarev, V., Dobrev, V., & Nikolov, S. (2018). First documented case of the killing of an Egyptian vulture (*Neophron percnopterus*) for belief-based practices in Western Africa. *Vie et Milieu*, *68*(1), 45-50.

Kumar, S., Pandey, N., Gore, K. G., Rather, T. A., & Atri, K. S. (2016). Conservation of vultures in and around Bandhavgarh Tiger Reserve. *Vulture News*, *70*, 42-68.

Liordos, V., Kontsiotis, V. J., Anastasiadou, M., & Karavasias, E. (2017). Effects of attitudes and demography on public support for endangered species conservation. *Science of the Total Environment*, *595*, 25-34.

Manigandan, S., Byju, H., Kannan, P., Ramakrishnan, B., & Vijayan, R. (2023). How availability of NSAIDs and public perception matters in vulture conservation in the Nilgiri biosphere reserve, South India: An overt and covert survey approach. *Ecology, Environment and Conservation*, *29*(3), 1340-1348.

Manigandan, S., Kannan, P., Byju, H., Bharathidasan, S., & Ramakrishnan, B. (2021). An attitude assessment of vulture conservation among three generations of residents of the Mudumalai Tiger Reserve, Tamil Nadu, Southern India. *Journal of Science and Technology*, *6*(03), 88-96.

Manqele, N. S., Selier, S. J., Taylor, J., & Downs, C. T. (2023). Vulture perceptions in a socio-ecological system: a case study of three protected areas in KwaZulu-Natal, South Africa. *Journal of Ornithology*, *164*(4), 789-801.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021a). Traditional health practitioners' and other community members' perceptions of vultures in the Kruger to Canyons biosphere region, South Africa. *Journal of Raptor Research*, *55*(3), 340-358.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021b). Uses of vultures in traditional medicines in the Kruger to Canyons Biosphere Region, South Africa. *Journal of Raptor Research*, *55*(3), 328-339.

Mateo-Tomás, P., & Olea, P. P. (2010). When hunting benefits raptors: a case study of game species and vultures. *European Journal of Wildlife Research*, *56*, 519-528.

McKean, S., Mander, M., Diederichs, N., Ntuli, L., Mavundla, K., Williams, V., & Wakelin, J. (2013). The impact of traditional use on vultures in South Africa. *Vulture News, 65*, 15-36.

Mmahi, O. P., & Usman, A. (2020). "Hunting Is Our Heritage; We Commit No Offence": Kainji National Park Wildlife Poachers, Kaiama, Kwara State Nigeria. *Deviant Behavior*, *41*(12), 1510-1523.

Morales-Reyes, Z., Martín-López, B., Moleón, M., Mateo-Tomás, P., Olea, P. P., Arrondo, E., Donázar, J. A., & Sánchez-Zapata, J. A. (2019). Shepherds' local knowledge and scientific data on the scavenging ecosystem service: Insights for conservation. *Ambio*, *48*(1), 48-60.

Muhammad, N., & Mustapha, Z. (2020). Collapsing towards extinction? Trade in birds carcasses for traditional medicine and the decline of vulture population in Katsina State, Nigeria. *Journal of Applied Sciences and Environmental Management*, *24*(4), 575-580.

Mulualem, G., & Tesfahunegny, W. (2015). Depredation of domestic fowl by birds of prey in low income rural households of Alamata Wereda, Southern Tigray, Ethiopia. *Journal of Zoology Studies, 2*(5), 22-29.

Murn, C., & Anderson, M. D. (2008). Activity patterns of African White-backed Vultures *Gyps africanus* in relation to different land-use practices and food availability. *Ostrich*, *79*(2), 191-198.

Murn, C., & Botha, A. (2018). A clear and present danger: impacts of poisoning on a vulture population and the effect of poison response activities. *Oryx*, *52*(3), 552-558.

Muthanna, A. (2019). Critical qualitative inquiry and methodological awareness: The effectiveness of face-to-face interviews in changing/enhancing participants' beliefs and practices. *International Journal of Research Studies in Education*, *8*(2), 59-66.

National Vulture Task Force. (2022). *Draft Biodiversity Management Plan (BMP) for the Conservation of Seven Vulture Species in South Africa*. South African Government Gazette, 47632, 70-71. https://www.dffe.gov.za/sites/default/files/sites/default/files/docs/publications/nemba_multispecies.bmp_southafricanvultures_g47632gon2817.pdf

Niraj, S. K., Krausman, P., & Dayal, V. (2012). A stakeholder perspective into wildlife policy in India. *Journal of Wildlife Management*, *76*(1), 10-18.

Oaks, J. L., & Watson, R. T. (2011). South Asian vultures in crisis: Environmental contamination with a pharmaceutical. In: Elliott, J. E., Bishop, C. A., Morrissey, C. A. (Eds). *Wildlife ecotoxicology: Forensic approaches* (pp. 413-441). Springer, New York.

Odino, M., Imboma, T., & Ogada, D. L. (2014). Assessment of the occurrence and threats to Hooded Vultures *Necrosyrtes monachus* in western Kenyan towns. *Vulture News, 67*(2), 3-20.

Odino, M., & Ogada, D. (2021). The intentional use of pesticides as poison in Kenya: Conservation and ecohealth impacts. In: Underkoffler, S.C., Adams, H. R. (Eds.), *Wildlife biodiversity conservation: Multidisciplinary and forensic approaches* (pp. 421-438). Springer Nature, Cham, Switzerland.

Ogada, D., Shaw, P., Beyers, R. L., Buij, R., Murn, C., Thiollay, J. M., Beale, C. M., Holdo, R. M., Pomeroy, D., Baker, N., Krüger, S. C., Botha, A., Virani, M. Z., Monadjem, A., & Sinclair, A. R. E. (2016). Another continental vulture crisis: Africa's vultures collapsing toward extinction. *Conservation Letters*, *9*(2), 89-97.

Ogada, D. L., Keesing, F., & Virani, M. Z. (2012). Dropping dead: causes and consequences of vulture population declines worldwide. *Annals of the New York Academy of Sciences, 1249*(1), 57-71.

Oliva-Vidal, P., Hernández-Matías, A., García, D., Colomer, M. À., Real, J., & Margalida, A. (2022). Griffon vultures, livestock and farmers: Unraveling a complex socio-economic ecological conflict from a conservation perspective. *Biological Conservation*, *272*, 109664. https://doi.org/10.1016/j.biocon.2022.109664

Oppel, S., Ruffo, A. D., Bakari, S., Tesfaye, M., Mengistu, S., Wondafrash, M., Endris, A., Pourchier, C., Ngari, A., & Arkumarev, V. (2022). Pursuit of 'sustainable'development may contribute to the vulture crisis in East Africa. *Bird Conservation International*, *32*(2), 173-187.

Otieno, P. O., Lalah, J. O., Virani, M., Jondiko, I. O., & Schramm, K.-W. (2011). Carbofuran use and abuse in Kenya: residues in soils, plants, water courses and the African white-backed vultures (*Gyps africanus*) found dead. *The Environmentalist*, *31*, 382-393.

Owolabi, B. A., Odewumi, S. O., & Agbelusi, E. A. (2020). Perceptions on population decline and ethno-cultural knowledge of Hooded Vulture (*Necrosyrtes monachus*) in southwest States of Nigeria. *Vulture News, 78*, 11-19.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., & Brennan, S. E. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *British Medical Journal*, *372*, 71.

Parker, C., Scott, S., & Geddes, A. (2019). Snowball sampling. In: Atkinson, P., Delamont S., Cernat, A., Sakshaug, J. W., Williams, R. A. (Eds.), *SAGE research methods foundations.* Sage.

Patricia, P., Acharya, S., Verma, T. P., Sharma, A., & Chaudhry, P. (2021). Ecotourism opportunities and conservation challenges: A case study involving some lesser known protected areas of central India landscape. *Asian Journal of Conservation Biology*, *10*(1), 46 -55.

Pfeiffer, M. B., Venter, J. A., & Downs, C. T. (2015). Identifying anthropogenic threats to Cape Vultures *Gyps coprotheres* using community perceptions in communal farmland, Eastern Cape Province, South Africa. *Bird Conservation International*, *25*(3), 353-365.

Phuyal, S., Ghimire, H. R., Shah, K. B., & Baral, H. S. (2016). Vultures and people: Local perceptions of a low-density vulture population in the eastern mid-hills of Nepal. *Journal of Threatened Taxa*, *8*(14), 9597-9609.

Piebeng, G. N. K., Mofor, G. Z., Tamungang, S. A., Djekillamber, D., Daksala, W., Bilal, M., & Teguia, A. (2023). Perception of Local Population of Manda National Park (Chad) on use of Vultures and the Impact of their Activities on the Conservation of Species. *American Journal of Environment Studies*, *6*(1), 1-18.

Prakash, V., Pain, D. J., Cunningham, A. A., Donald, P., Prakash, N., Verma, A., Gargi, R., Sivakumar, S., & Rahmani, A. R. (2003). Catastrophic collapse of Indian white-backed *Gyps bengalensis* and long-billed *Gyps indicus* vulture populations. *Biological Conservation*, *109*(3), 381-390.

Punch, K. F. (2013). *Introduction to social research: Quantitative and qualitative approaches*. Sage, Melbourne.

Ramos, S. C. (2018). Considerations for culturally sensitive traditional ecological knowledge research in wildlife conservation. *Wildlife Society Bulletin*, *42*(2), 358-365.

R Core Team. (2022). R: A language and environment for statistical computing (Version 4.2.1) [Software]. R Foundation for Statistical Computing.

Reynolds, J., Ibáñez-Álamo, J. D., Sumasgutner, P., & Mainwaring, M. C. (2019). Urbanisation and nest building in birds: a review of threats and opportunities. *Journal of Ornithology*, *160*(3), 841-860.

Ryan, G. W., & Bernard, H. R. (2000). Techniques to identify themes in qualitative data. *Field Methods*, 15, 85-109.

Safford, R., Andevski, J., Botha, A., Bowden, C. G., Crockford, N., Garbett, R., Margalida, A., Ramírez, I., Shobrak, M., & Tavares, J. (2019). Vulture conservation: the case for urgent action. *Bird Conservation International*, *29*(1), 1-9.

Saidu, Y., & Buij, R. (2013). Traditional medicine trade in vulture parts in northern Nigeria. *Vulture News*, *65*, 4-14.

Salazar, M. K. (1990). Interviewer bias: How it affects survey research. *Aaohn Journal*, *38*(12), 567-572.

Salom, A., Suárez, M. E., Destefano, C. A., Cereghetti, J., Vargas, F. H., & Grande, J. M. (2021). Human-wildlife conflicts in the Southern Yungas: what role do raptors play for local settlers? *Animals*, *11*(5), 1428.

Samson, A., & Ramakarishnan, B. (2016). Observation of a population of Egyptian Vultures *Neophron percnopterus* in Ramanagaram Hills, Karnataka, southern India. *Vulture News*, *71*, 36-49.

Samson, A., & Ramakrishnan, B. (2020). The critically endangered White-rumped Vulture *Gyps bengalensis* in Sigur Plateau, Western Ghats, India: Population, breeding ecology, and threats. *Journal of Threatened Taxa*, *12*(13), 16752-16763.

Sánchez-Pedraza, R., Gamba-Rincón, M. R., & González-Rangel, A. L. (2012). Use of black vulture (*Coragyps atratus*) in complementary and alternative therapies for cancer in Colombia: A qualitative study. *Journal of Ethnobiology and Ethnomedicine*, *8*, 1-8.

Santangeli, A., Arkumarev, V., Komen, L., Bridgeford, P., & Kolberg, H. (2017). Unearthing poison use and consequent anecdotal vulture mortalities in Namibia's commercial farmland–implications for conservation. *Ostrich*, *88*(2), 147-154.

Santangeli, A., Arkumarev, V., Rust, N., & Girardello, M. (2016). Understanding, quantifying and mapping the use of poison by commercial farmers in Namibia–Implications for scavengers' conservation and ecosystem health. *Biological Conservation*, *204*, 205-211.

Santangeli, A., Buechley, E., Mammola, S., & Lambertucci, S. A. (2022). Priorities for research and action to prevent a New World vulture crisis. *Biological Conservation*, *270*, 109563. https://doi.org/10.1016/j.biocon.2022.109563

Scholtz, S. E. (2021). Sacrifice is a step beyond convenience: A review of convenience sampling in psychological research in Africa. *SA Journal of Industrial Psychology*, *47*(1), 1-12.

Sekercioglu, C. H. (2003). Birding Economics: Conservation through Commodification. *Quarterly Review of Biology*, *78*(1), 106.

Shah, G., Anadon, J. D., Jha, P. K., & Singh, N. B. (2019). Distribution of vulture species and their nesting in Chitwan-Annapurna Landscape (CHAL), Nepal. *Bird Conservation Nepal*, *8*, 5-9.

Shumsher, K., & Timilsina, Y. (2013). Factors Affecting Peoples' Participation on Vulture Conservation from Kaski district of Nepal. *Conservation Science*, *1*(1), 19-26.

Singh, R., Behera, S., & Sethy, J. (2024). Evaluating the effectiveness of wildlife protection laws in Uttar Pradesh: an analysis of enforcement and prosecution. *Journal of Wildlife and Biodiversity*, *8*(2), 385-396.

Sirakaya-Turk, E., & Uysal, M. (2011). Survey research: sampling and questionnaire design.

Stara, K., Saravia-Mullin, V., Tsiakiris, R., Adefolu, S., Akyol, A., Akyol, R. İ., Asswad, N. G., Çetin, T., Dayyoub, M., Dushi, G., Ivande, S. T., Kordopatis, P., Kret, E., Özuslu, S., Petrovski, N., Simeonova, I., Spassova, Y., Qaneer, T. E., Pourchier, C., Saad, L. J., Elsafoury, H., Topi, M., Trajçe, A., Ziu, D., & Nikolov, S. C. (2022). Following the White Vulture: Ethno-ornithology along the Flyway of the Egyptian Vulture (*Neophron percnopterus*). *Human Ecology*, *50*(4), 725-738.

Subedi, T. R., Virani, M. Z., Gurung, S., Buij, R., Baral, H. S., Buechley, E. R., Anadón, J. D., & Sah, S. A. (2018). Estimation of population density of bearded vultures using line-transect distance sampling and identification of perceived threats in the Annapurna Himalaya range of Nepal. *Journal of Raptor Research*, *52*(4), 443-453.

Van, T. P., Le Duc, O., Leprince, B., Bordes, C., Luu, V. Q., & Luiselli, L. (2020). Hunters' structured questionnaires enhance ecological knowledge and provide circumstantial survival evidence for the world's rarest turtle. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *30*(1), 183-193.

Wahl, M. L., McWherter, B., Zollner, P. A., Ma, Z., Burcham, G. N., Humberg, L. A., & Kluever, B. M. (2023). Livestock producers' perceptions of the American black vulture conflict in the midwestern United States. *Wildlife Society Bulletin*, *47*(2), e1440. https://doi.org/10.1002/wsb.1440

White, P. C., Jennings, N. V., Renwick, A. R., & Barker, N. H. (2005). Questionnaires in ecology: a review of past use and recommendations for best practice. *Journal of Applied Ecology*, *42*(3), 421-430.

Williams, M. M., Ottosson, U., Tende, T., & Deikumah, J. P. (2021). Traditional belief systems and trade in vulture parts are leading to the eradication of vultures in Nigeria: an ethno-ornithological study of north-central Nigeria. *Ostrich*, *92*(3), 194-202.

Williams, R. S., Jara, J. L., Matsufuiji, D., & Plenge, A. (2011). Trade in Andean condor *Vulture gryphus* feathers and body parts in the city of Cusco and the Sacred Valley, Cusco region, Peru. *Vulture News*, *61*, 16-26.

Yamada, N. (2011). Why tour guiding is important for ecotourism: Enhancing guiding quality with the ecotourism promotion policy in Japan. *Asia Pacific Journal of Tourism Research*, *16*(2), 139-152.

Yee, N., Shaffer, L. J., Gore, M. L., Bowerman, W. W., & Harrell, R. M. (2021). Expert perceptions of conflicts in African vulture conservation: Implications for overcoming ethical decision-making dilemmas. *Journal of Raptor Research*, *55*(3), 359-373.

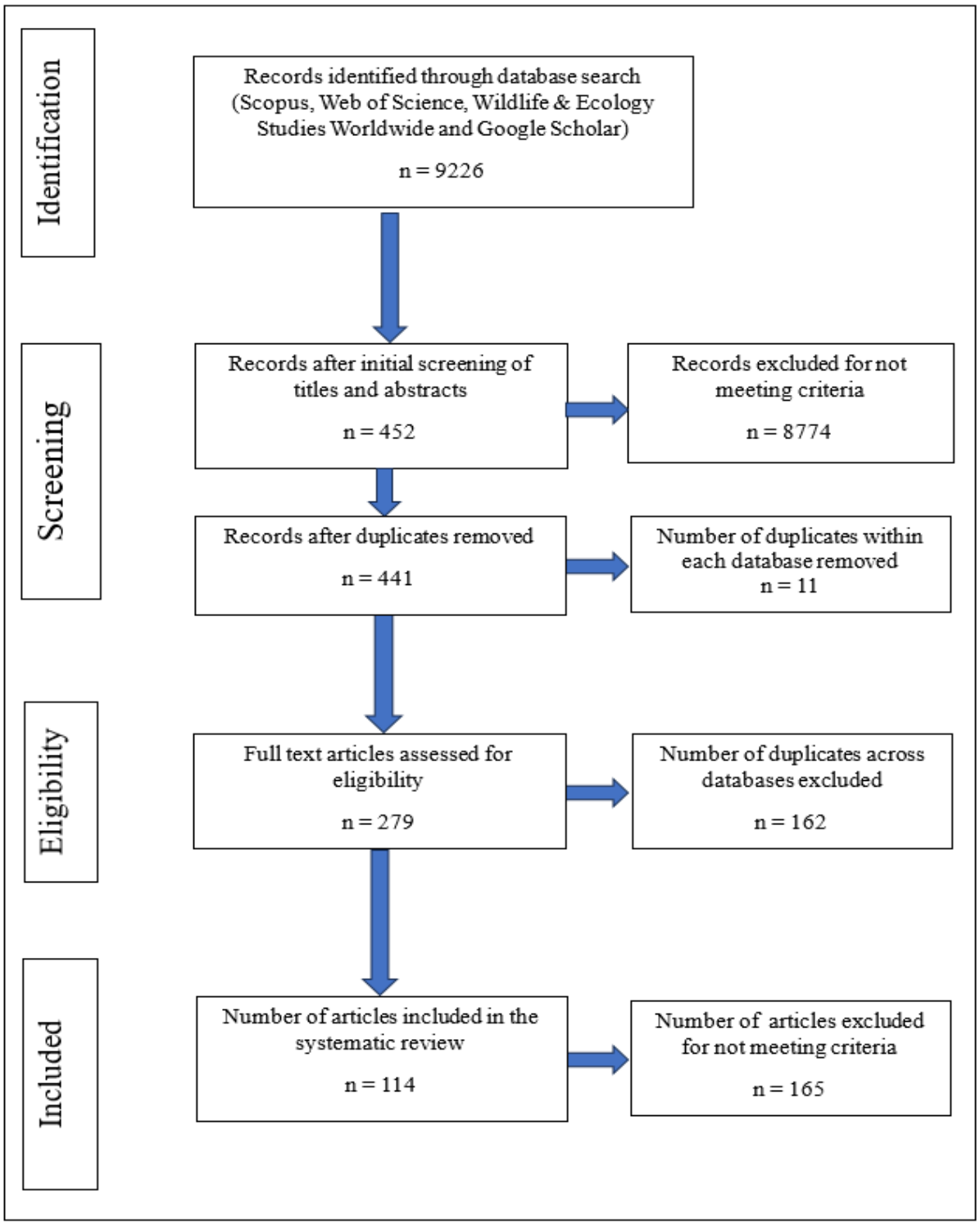
Zuberogoitia, I., Zabala, J., Martínez, J., Martínez, J., & Azkona, A. (2008). Effect of human activities on Egyptian vulture breeding success. *Animal Conservation*, *11*(4), 313-320.

2.8 Supplementary information

Supplementary Information Table S2.1: Search strings used for systematic review. This table presents the search strings used to retrieve relevant articles for the systematic review on questionnaire-based vulture research. Each search string is listed along with the databases in which it was used.

Database	Search String
Web of Science	TS=((Vulture* OR Condor OR Aegypius monachus OR Cathartes aura OR Cathartes burrovianus OR Cathartes melambrotus OR Coragyps atratus OR Gypaetus barbatus OR Gyps fulvus OR Gypohierax angolensis OR Gyps africanus OR Gyps bengalensis OR Gyps coprotheres OR Gyps himalayensis OR Gyps indicus OR Gyps rueppelli OR Gyps tenuirostris OR Gymnogyps californianus OR Necrosyrtes monachus OR Neophron percnopterus OR Sarcoramphus papa OR Sarcogyps calvus OR Torgos tracheliotos OR Trigonoceps occipitalis OR Vultur gryphus)) AND TS=((survey* OR questionnaire* OR interview* OR perception* OR opinion* OR attitude*)) NOT TS=((road OR roadside OR transect OR aerial OR field))
Scopus	TITLE-ABS-KEY ("vulture") OR TITLE-ABS-KEY(“Condor”) OR TITLE-ABS-KEY ("Aegypius monachus") OR TITLE-ABS-KEY ("Cathartes aura") OR TITLE-ABS-KEY ("Cathartes burrovianus") OR TITLE-ABS-KEY ("Cathartes melambrotus") OR TITLE-ABS-KEY ("Coragyps atratus") OR TITLE-ABS-KEY ("Gypaetus barbatus") OR TITLE-ABS-KEY ("Gypohierax angolensis") OR TITLE-ABS-KEY ("Gyps africanus") OR TITLE-ABS-KEY ("Gyps bengalensis") OR TITLE-ABS-KEY ("Gyps coprotheres") OR TITLE-ABS-KEY ("Gyps fulvus") OR TITLE-ABS-KEY ("Gyps himalayensis") OR TITLE-ABS-KEY ("Gyps indicus") OR TITLE-ABS-KEY ("Gyps rueppelli") OR TITLE-ABS-KEY ("Gyps tenuirostris") OR TITLE-ABS-KEY ("Gymnogyps californianus") OR TITLE-ABS-KEY ("Necrosyrtes monachus") OR TITLE-ABS-KEY ("Neophron percnopterus") OR TITLE-ABS-KEY ("Sarcoramphus papa") OR TITLE-ABS-KEY ("Sarcogyps calvus") OR TITLE-ABS-KEY ("Torgos tracheliotos") OR TITLE-ABS-KEY ("Trigonoceps occipitalis") OR TITLE-ABS-KEY ("Vultur gryphus") AND TITLE-ABS-KEY ("vulture") AND TITLE-ABS-KEY ("perception") OR TITLE-ABS-KEY ("questionnaire") OR TITLE-ABS-KEY ("survey") OR TITLE-ABS-KEY ("interview") OR TITLE-ABS-KEY ("opinion") OR TITLE-ABS-KEY ("attitude") AND NOT TITLE-ABS-KEY ("road") OR TITLE-ABS-KEY ("roadside") OR TITLE-ABS-KEY ("transect") OR TITLE-ABS-KEY ("arial") OR TITLE-ABS-KEY ("aerial") OR TITLE-ABS-KEY ("field")
Wildlife & Ecology Studies Worldwide	TX=(Vulture OR Condor OR Aegypius monachus OR Cathartes aura OR Cathartes burrovianus OR Cathartes melambrotus OR Coragyps atratus OR Gypaetus barbatus OR Gypohierax angolensis OR Gyps africanus OR Gyps bengalensisOR Gyps coprotheres OR Gyps fulvus OR Gyps himalayensis OR Gyps indicus OR Gyps rueppelli OR Gyps tenuirostris OR Gymnogyps californianus OR Necrosyrtes monachus OR Neophron percnopterus OR Sarcoramphus papa OR Sarcogyps calvus OR Torgos tracheliotos OR Trigonoceps occipitalis OR Vultur gryphus AND survey OR questionnaire OR interview OR perception OR opinion OR attitude) NOT AB=(road OR roadside OR transect OR arial OR aerial OR field)
Google Scholar	Find articles with all of the words "Vulture", with at least one of the words "Questionnaire, Survey", without the words "Road, Transect, Aerial, Field"

Supplementary Information Figure S2.1: Schematic diagram illustrating the study selection process. This diagram depicts the systematic review process, which included the identification, screening, eligibility assessment, and inclusion of articles. Each stage indicates the number of articles at that phase, highlighting the progression from initial identification to final inclusion in the review.



Supplementary Information Table S2.2: Countries with vulture populations and corresponding number of questionnaire studies.

Country	Number of Questionnaire Studies on Vultures
Afghanistan	0
Albania	3
Algeria	0
Andorra	0
Angola	0
Argentina	4
Armenia	0
Aruba	0
Austria	0
Azerbaijan	0
Bahamas	0
Bangladesh	0
Barbados	0
Belize	0
Benin	0
Bermuda	0
Bhutan	0
Bolivia	1
Bosnia and Herzegovina	0
Botswana	0
Brazil	0
Brunei	0
Bulgaria	1
Burkina Faso	2
Burundi	0
Cabo Verde	1
Cambodia	0
Cameroon	0
Canada	0
Cayman Islands	0
Central African Republic	0
Chad	1
Chile	1
China	1
Colombia	2
Congo	0
Costa Rica	1
Côte d'Ivoire	0
Croatia	0
Cuba	0

Cyprus	0
Czechia	0
Democratic Republic of the Congo	0
Djibouti	0
Dominica	0
Dominican Republic	0
Ecuador	0
Egypt	1
El Salvador	0
Equatorial Guinea	0
Eritrea	0
Eswatini	0
Ethiopia	3
Falkland Islands	0
France	2
French Guiana	0
Gabon	0
Gambia	0
Georgia	0
Germany	0
Ghana	5
Gibraltar	0
Greece	4
Grenada	0
Guatemala	0
Guinea	0
Guinea-Bissau	1
Guyana	0
Haiti	0
Honduras	0
Hungary	0
India	12
Iran	0
Iraq	0
Israel	3
Italy	0
Jamaica	0
Jordan	1
Kazakhstan	0
Kenya	4
Kuwait	0
Kyrgyzstan	0
Lao	0
Latvia	0
Lebanon	1
Lesotho	1

Liberia	0
Libya	0
Malawi	0
Malaysia	0
Mali	0
Malta	0
Martinique	0
Mauritania	0
Mexico	0
Mongolia	0
Montenegro	0
Morocco	0
Mozambique	0
Myanmar	0
Namibia	5
Nepal	12
Netherlands	0
Nicaragua	0
Niger	2
Nigeria	12
North Macedonia	1
Oman	0
Pakistan	1
Palestine	0
Panama	0
Paraguay	0
Peru	2
Poland	0
Portugal	1
Puerto Rico	0
Romania	0
Russia	0
Rwanda	0
Saint Kitts and Nevis	0
Saint Lucia	0
Saint Vincent and the Grenadines	0
Saudi Arabia	0
Senegal	0
Serbia	0
Sierra Leone	0
Slovakia	0
Slovenia	0
Somalia	0
South Africa	15
South Georgia and the South Sandwich Islands	0
South Korea	0

South Sudan	0
Spain	0
Sudan	0
Suriname	0
Switzerland	1
Syria	1
Taiwan	0
Tajikistan	0
Tanzania	0
Thailand	0
Togo	0
Trinidad and Tobago	0
Tunisia	0
Turkey	1
Turkmenistan	0
U.S. Virgin Islands	0
Uganda	0
Ukraine	0
United Arab Emirates	0
United States of America	3
Uruguay	0
Uzbekistan	0
Venezuela	0
Viet Nam	0
Western Sahara	0
Yemen	0
Zambia	0
Zimbabwe	2

Supplementary Information Table S2.3: The stakeholder groups and key themes identified in questionnaire-based vulture studies.

Stakeholder Group	Country	Continent	Theme 1	Theme 2
Agricultural shop owners	Kenya	Africa	Pesticide toxicity	Unintentional poisoning
Agricultural shop owners	Nepal	Asia	Public perception of vultures	Threats to vultures
Birdwatchers	Costa Rica	North America	Public perception of vultures	
Businessmen	Nepal	Asia	Public perception of vultures	
Butchers/Abattoir staff	Burkina Faso	Africa	Intentional poisoning	Threats to vultures
Butchers/Abattoir staff	Ghana	Africa	Public perception of vultures	
Butchers/Abattoir staff	India	Africa	Public perception of vultures	Traditional medicine
Butchers/Abattoir staff	Burkina Faso	Africa	Public perception of vultures	Traditional medicine
Butchers/Abattoir staff	Guinea-Bissau	Africa	Public perception of vultures	Threats to vultures
Butchers/Abattoir staff	India	Africa	Public perception of vultures	
Butchers/Abattoir staff	Chad	Africa	Public perception of vultures	Public knowledge of vultures
Butchers/Abattoir staff	Ghana	Africa	Public perception of vultures	
Butchers/Abattoir staff	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Butchers/Abattoir staff	Kenya	Africa	Unintentional poisoning	Threats to vultures
Buyers of illegally traded vultures	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Cancer patients	Colombia	South America	Traditional medicine	Public perception of vultures
Community members	India	Asia	Carcass disposal methods	Public perception of vultures
Community members	Zimbabwe	Africa	Carcass disposal methods	
Community members	Nepal	Asia	Carcass disposal methods	Threats to vultures
Community members	Nepal	Asia	Economic value of vultures	
Community members	India	Asia	Economic value of vultures	
Community members	India	Asia	Food availability	Population distribution
Community members	Nepal	Asia	NSAID toxicity	Carcass disposal methods
Community members	Argentina	South America	Perceived vulture attacks	Public perception of vultures
Community members	India	Asia	Population distribution	NSAID toxicity
Community members	Nepal	Asia	Population distribution	Threats to vultures
Community members	India	Asia	Population distribution	Carcass disposal methods
Community members	Nepal	Asia	Public perception of vultures	
Community members	India	Asia	Public knowledge of vultures	
Community members	Nigeria	Africa	Public perception of vultures	Public knowledge of vultures
Community members	Cabo Verde	Africa	Public perception of vultures	Threats to vultures
Community members	Argentina	South America	Public perception of vultures	
Community members	Greece	Europe	Public perception of vultures	
Community members	Nepal	Asia	Public perception of vultures	
Community members	Ghana	Africa	Public perception of vultures	
Community members	India	Asia	Public perception of vultures	Traditional medicine

Community members	South Africa	Africa	Public perception of vultures	Threats to vultures
Community members	Zimbabwe	Africa	Public perception of vultures	Traditional medicine
Community members	Burkina Faso	Africa	Public perception of vultures	Traditional medicine
Community members	India	Asia	Public perception of vultures	
Community members	Ethiopia	Africa	Public perception of vultures	
Community members	Ghana	Africa	Public perception of vultures	
Community members	Nigeria	Africa	Public perception of vultures	Threats to vultures
Community members	Pakistan	Asia	Public perception of vultures	NSAID toxicity
Community members	Spain	Europe	Public perception of vultures	
Community members	Greece	Europe	Public perception of vultures	
Community members	China	Asia	Public perception of vultures	Traditional medicine
Community members	Chile	South America	Public perception of vultures	Public knowledge of vultures
Community members	Namibia	Africa	Public perception of vultures	Unintentional poisoning
Community members	Colombia	South America	Public perception of vultures	Public knowledge of vultures
Community members	Ghana	Africa	Public perception of vultures	
Community members	Nepal	Asia	Public perception of vultures	Carcass disposal methods
Community members	South Africa	Africa	Public perception of vultures	Carcass disposal methods
Community members	Nepal	Asia	Public perception of vultures	Threats to vultures
Community members	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Community members	Niger; Nigeria	Africa	Traditional medicine	Poaching
Community members	Nigeria	Africa	Traditional medicine	Poaching
Community members	Nigeria	Africa	Traditional medicine	
Community members	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Community members	Albania	Europe	Unintentional poisoning	Threats to vultures
Community members; Farmers; Veterinary practitioners	Nepal	Asia	Public perception of vultures	Carcass disposal methods
Conservationists	Kenya	Africa	Pesticide toxicity	Unintentional poisoning
Conservationists	South Africa; Kenya	Africa	Public perception of vultures	
Conservationists	India	Asia	Public perception of vultures	Traditional medicine
Conservationists	Guinea-Bissau	Africa	Public perception of vultures	Threats to vultures
Cultural/religious authorities	Guinea-Bissau	Africa	Public perception of vultures	Threats to vultures
Farmers	Portugal	Europe	Antibiotic toxicity	Carcass disposal methods
Farmers	India	Asia	Carcass disposal methods	Public perception of vultures
Farmers	France	Europe	Carcass disposal methods	Public perception of vultures
Farmers	South Africa	Africa	Food availability	Population distribution
Farmers	Albania	Europe	Intentional poisoning	Pesticide toxicity
Farmers	India	Asia	NSAID toxicity	Rabies transmission
Farmers	Spain	Europe	Perceived vulture attacks	Public perception of vultures

Farmers	Argentina	South America	Perceived vulture attacks	Public perception of vultures
Farmers	South Africa	Africa	Perceived vulture attacks	Public perception of vultures
Farmers	Kenya	Africa	Pesticide toxicity	Unintentional poisoning
Farmers	Kenya	Africa	Pesticide toxicity	Unintentional poisoning
Farmers	South Africa	Africa	Population distribution	
Farmers	India	Asia	Population distribution	NSAID toxicity
Farmers	India	Asia	Population distribution	Carcass disposal methods
Farmers	South Africa	Africa	Population distribution	
Farmers	Nepal	Asia	Public perception of vultures	
Farmers	Spain	Europe	Public knowledge of vultures	Public knowledge of vultures
Farmers	Argentina	South America	Public perception of vultures	Public knowledge of vultures
Farmers	Bolivia	South America	Public perception of vultures	Public knowledge of vultures
Farmers	Cabo Verde	Africa	Public perception of vultures	Threats to vultures
Farmers	Costa Rica	North America	Public perception of vultures	
Farmers	Namibia	Africa	Public perception of vultures	Threats to vultures
Farmers	Argentina	South America	Public perception of vultures	
Farmers	Ghana	Africa	Public perception of vultures	
Farmers	Spain	Europe	Public perception of vultures	
Farmers	India	Asia	Public perception of vultures	Traditional medicine
Farmers	South Africa	Africa	Public perception of vultures	Threats to vultures
Farmers	USA	North America	Public perception of vultures	Perceived vulture attacks
Farmers	Nepal	Asia	Public perception of vultures	
Farmers	Guinea-Bissau	Africa	Public perception of vultures	Threats to vultures
Farmers	India	Asia	Public perception of vultures	
Farmers	Nepal	Asia	Public perception of vultures	Carcass disposal methods
Farmers	Chad	Africa	Public perception of vultures	Public knowledge of vultures
Farmers	South Africa	Africa	Public perception of vultures	Unintentional poisoning
Farmers	Spain	Europe	Public perception of vultures	
Farmers	Nigeria	Africa	Public perception of vultures	Threats to vultures
Farmers	Spain	Europe	Public perception of vultures	
Farmers	Greece	Europe	Public perception of vultures	
Farmers	India	Asia	Public perception of vultures	Carcass disposal methods
Farmers	Namibia	Africa	Public perception of vultures	Unintentional poisoning
Farmers	Ghana	Africa	Public perception of vultures	
Farmers	Nepal	Asia	Public perception of vultures	Threats to vultures
Farmers	Nepal	Asia	Threats to vultures	Public perception of vultures
Farmers	Nigeria	Africa	Traditional medicine	Illegal trade of vultures

Farmers	Nigeria	Africa	Traditional medicine	
Farmers	Kenya	Africa	Unintentional poisoning	
Farmers	Argentina	South America	Unintentional poisoning	
Farmers	Ethiopia	Africa	Unintentional poisoning	
Farmers	Albania	Europe	Unintentional poisoning	Threats to vultures
Farmers	Namibia	Africa	Unintentional poisoning	Public perception of vultures
Farmers	Namibia	Africa	Unintentional poisoning	Threats to vultures
Fishermen	Cabo Verde	Africa	Public perception of vultures	Threats to vultures
Forestry officials	Burkina Faso	Africa	Intentional poisoning	Threats to vultures
Forestry officials	India	Asia	Population distribution	Threats to vultures
Forestry officials	India	Asia	Public knowledge of vultures	
Forestry officials	Chad	Africa	Public perception of vultures	Public knowledge of vultures
Forestry officials	Greece	Europe	Public perception of vultures	
Gardeners	Chad	Africa	Public perception of vultures	Public knowledge of vultures
Government officials	South Africa	Africa	Population distribution	
Government officials	Guinea-Bissau	Africa	Public perception of vultures	Threats to vultures
Government officials	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Hunters	Spain	Europe	Food availability	
Hunters	USA	North America	Lead toxicity	
Hunters	South Africa	Africa	Predation	
Hunters	Nigeria	Africa	Public perception of vultures	Threats to vultures
Hunters	Spain	Europe	Public perception of vultures	
Hunters	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Land managers	South Africa	Africa	Population distribution	
Landowners	South Africa	Africa	Population distribution	
Landowners	India	Asia	Public perception of vultures	
Landfill staff	India	Asia	Carcass disposal methods	
Landfill staff	Kenya	Africa	Unintentional poisoning	Threats to vultures
Law enforcement	Burkina Faso	Africa	Intentional poisoning	Threats to vultures
Livestock owners	Ethiopia	Africa	Perceived vulture attacks	Public perception of vultures
Livestock owners	Pakistan	Asia	Public perception of vultures	NSAID toxicity
Manual labourers	Nepal	Asia	Public perception of vultures	
Members of the public	Costa Rica	North America	Public perception of vultures	
Ornithologists	India	Asia	Population distribution	Threats to vultures
Pest control products board	Kenya	Africa	Pesticide toxicity	Unintentional poisoning
Pharmaceutical distributers	Spain	Europe	NSAID toxicity	
Pharmacists	Albania	Europe	Intentional poisoning	Pesticide toxicity
Pharmacists	India	Asia	NSAID toxicity	
Pharmacists	India	Asia	Public perception of vultures	

Pharmacists	India	Asia	Public perception of vultures	Carcass disposal methods
Pilots	Namibia	Africa	Collisions with aircrafts	
Poachers	Nigeria	Africa	Poaching	
Poachers	Albania	Europe; Asia; Africa	Public perception of vultures	Public knowledge of vultures
Poachers	Bulgaria	Europe	Public perception of vultures	Public knowledge of vultures
Poachers	Greece	Europe	Public perception of vultures	Public knowledge of vultures
Poachers	Macedonia	Europe	Public perception of vultures	Public knowledge of vultures
Poachers	Turkey	Asia	Public perception of vultures	Public knowledge of vultures
Poachers	Syria	Asia	Public perception of vultures	Public knowledge of vultures
Poachers	Lebanon	Asia	Public perception of vultures	Public knowledge of vultures
Poachers	Jordan	Asia	Public perception of vultures	Public knowledge of vultures
Poachers	Egypt	Africa	Public perception of vultures	Public knowledge of vultures
Poachers	Niger	Africa	Public perception of vultures	Public knowledge of vultures
Poachers	Nigeria	Africa	Public perception of vultures	Public knowledge of vultures
Poachers	Nigeria	Africa	Traditional medicine	
Poachers	South Africa	Africa	Traditional medicine	Illegal trade of vultures
Rangers	India	Asia	Population distribution	NSAID toxicity
Rangers	Spain	Europe	Public perception of vultures	
SFS management	Spain	Europe	Public perception of vultures	Public knowledge of vultures
SFS management	France	Europe	Public perception of vultures	Public knowledge of vultures
SFS managers	Spain	Europe	Economic value of vultures	Public perception of vultures
SFS managers	France	Europe	Economic value of vultures	Public perception of vultures
SFS managers	South Africa	Africa	SFS management	Public perception of vultures
SFS managers	South Africa	Africa	SFSs	Carcass disposal methods
SFS visitors	Spain	Europe	Economic value of vultures	Public perception of vultures
SFS visitors	France	Europe	Economic value of vultures	Public perception of vultures
SFS visitors	Spain	Europe	Public perception of vultures	Public knowledge of vultures
SFS visitors	France	Europe	Public perception of vultures	Public knowledge of vultures
Students	Nigeria	Africa	NSAID toxicity	Public perception of vultures
Students	India	Asia	Population distribution	NSAID toxicity
Students	Nepal	Asia	Public perception of vultures	
Students	Ghana	Africa	Public knowledge of vultures	Carcass disposal methods

Teachers	Nigeria	Africa	NSAID toxicity	Public perception of vultures
Teachers	Nepal	Asia	Public perception of vultures	
Teachers	Ghana	Africa	Public knowledge of vultures	Carcass disposal methods
Tourist centre staff	Greece	Europe	Public perception of vultures	
Tourists at national parks/nature reserves	Israel	Asia	Economic value of vultures	
Tourists at national parks/nature reserves	Israel	Asia	Economic value of vultures	
Tourists at national parks/nature reserves	Peru	South America	Economic value of vultures	
Tourists at national parks/nature reserves	Greece	Europe	Public perception of vultures	
Tourists at national parks/nature reserves	Spain	Europe	Public perception of vultures	
Traders	Cabo Verde	Africa	Public perception of vultures	Threats to vultures
Traders	Ghana	Africa	Public perception of vultures	
Traders	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Traditional health practitioners	Guinea-Bissau	Africa	Public perception of vultures	Threats to vultures
Traditional health practitioners	Chad	Africa	Public perception of vultures	Public knowledge of vultures
Traditional health practitioners	Ghana	Africa	Public perception of vultures	
Traditional health practitioners	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Traditional health practitioners	Ghana	Africa	Traditional medicine	
Traditional health practitioners	South Africa	Africa	Traditional medicine	Public perception of vultures
Traditional health practitioners	South Africa	Africa	Traditional medicine	Illegal trade of vultures
Traditional health practitioners	South Africa	Africa	Traditional medicine	
Traditional health practitioners; Community members	South Africa	Africa	Traditional medicine	Public perception of vultures
Veterinary practitioners	Israel	Asia	Economic value of vultures	
Veterinary practitioners	Burkina Faso	Africa	Intentional poisoning	Threats to vultures
Veterinary practitioners	Nigeria	Africa	NSAID toxicity	Public perception of vultures
Veterinary practitioners	India	Asia	NSAID toxicity	
Veterinary practitioners	India	Asia	NSAID toxicity	Public perception of vultures
Veterinary practitioners	Global	Global	NSAID toxicity	
Veterinary practitioners	Guinea-Bissau	Africa	Public perception of vultures	Threats to vultures
Veterinary practitioners	India	Asia	Public perception of vultures	
Veterinary practitioners	Nepal	Asia	Public perception of vultures	Carcass disposal methods
Veterinary practitioners	Pakistan	Asia	Public perception of vultures	NSAID toxicity
Veterinary practitioners	India	Asia	Public perception of vultures	Carcass disposal methods
Veterinary practitioners	Ghana	Africa	Public perception of vultures	
Veterinary practitioners	Nepal	Asia	Public perception of vultures	Threats to vultures

Village chiefs	Chad	Africa	Public perception of vultures	Public knowledge of vultures
Wildlife experts	India	Asia	Population distribution	Threats to vultures
Wildlife sanctuary/rehabilitation centre/zoo staff	Global	Global	NSAID toxicity	
Wildlife sanctuary/rehabilitation centre/zoo staff	Global	Global	NSAID toxicity	
Wildlife sanctuary/rehabilitation centre/zoo staff	South Africa	Africa	Predation	
Wildlife traders	Albania	Europe	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Bulgaria	Europe	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Greece	Europe	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Macedonia	Europe	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Turkey	Asia	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Syria	Asia	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Lebanon	Asia	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Jordan	Asia	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Egypt	Africa	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Niger	Africa	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Nigeria	Africa	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Chad	Africa	Public perception of vultures	Public knowledge of vultures
Wildlife traders	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Wildlife traders	Nigeria	Africa	Traditional medicine	Illegal trade of vultures
Wildlife traders	Nigeria	Africa	Traditional medicine	
Wildlife traders	South Africa	Africa	Traditional medicine	Illegal trade of vultures
Wildlife traders	Lesotho	Africa	Traditional medicine	
Wildlife traders	Peru	South America	Traditional medicine	Knowledge of vultures
Wildlife traders	Nigeria	Africa	Traditional Medicine	Illegal trade of vultures
Zoo visitors	USA	North America	Public perception of vultures	
Zoo visitors	Switzerland	Europe	Public perception of vultures	

CHAPTER 3

Public perception of marking wildlife with monitoring devices for research purposes

Emma B. Laurieston[1], Lindy J. Thompson[1,2,3], Louise Swemmer[4] and Colleen T. Downs[*1]

[1]*Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg, 3209, South Africa*

[2]*Birds of Prey Programme, Endangered Wildlife Trust, Midrand, South Africa*

[3]*Southern African Wildlife College, Kempiana Nature Reserve, Hoedspruit, South Africa*

[4]*Scientific Services, Private Bag X402, Skukuza 1350 South Africa.*

Formatted as a manuscript for submission to an international peer-reviewed journal.

* Corresponding author: Colleen T. Downs

Email: downs@ukzn.ac.za; ORCID: http://orcid.org/0000-0001-8334-1510

Emails and ORCIDs of other authors:

Emma B. Laurieston Email: emmalaurieston4@gmail.com; ORCID: https://orcid.org/0009-0009-4157-2359

Lindy Thompson Email: LindyJane.Thompson@gmail.com; ORCID: https://orcid.org/0000-0001-9847-2003

Louise Swemmer Email: louise.swemmer@sanparks.org

Running header: Public perception of wing-tagging vultures

3.1 Abstract

Wildlife tracking and monitoring devices play a pivotal role in advancing our knowledge of animal behaviour and ecology. However, public perception of these tools significantly influences support and involvement in conservation initiatives. In this study, we interviewed 207 participants, including conservation professionals, field guides, international tourists, locals, and wildlife photographers, to gauge their attitudes toward wildlife marking techniques and vulture conservation. We used an in-person, semi-structured pilot questionnaire, followed by a structured in-person and online questionnaire. Our findings reveal a high level of awareness among participants regarding the purposes and importance of marking wildlife for research and conservation. However, concerns for animal welfare were expressed alongside recognition of the necessity of these techniques. Specifically, all participants endorsed the significance of patagial (wing) tagging vultures and expressed a willingness to contribute to vulture research by reporting sightings of tagged individuals. This study demonstrates the widespread acknowledgement of the value of wildlife marking techniques across diverse stakeholder groups. We recommend ongoing public education initiatives aimed at deepening understanding of the specific purposes behind wildlife marking and encouraging active involvement and support for monitoring efforts. To this end, targeted educational campaigns and outreach programs should be developed to raise awareness and increase public engagement in wildlife-marking conservation endeavours.

Keywords: Wildlife monitoring, Public perception, Conservation, Vulture conservation, Animal welfare

3.2 Introduction

Advancements in technology have caused a great shift in wildlife research techniques, deepening our understanding of animal behaviour and ecology (McMahon et al., 2011; Cooke et al., 2017). Novel tracking methods, such as global positioning systems (GPS), have allowed researchers to overcome the limitations of traditional methods, such as direct observation, which often had time constraints, and caused disruption to the study subjects (Iredale et al., 2010). With new technology, researchers have been able to remotely track animals, with minimal disturbance (Curk et al., 2021). This has uncovered migratory routes, natural behaviour and habitat preferences of even the most elusive species (Kendall & Virani, 2012; Casas et al., 2015), greatly benefitting conservation science. Although GPS devices allow for the collection of vast amounts of spatial and temporal data, in real-time, other popular yet less effective marking methods are used to monitor wildlife (Kendall & Virani, 2012). These include VHF telemetry collars (Broekhuis et al., 2019) and identification (ID) markings, such as ID tags, tattoos, or brandings, all of which require a researcher to be in the field to collect data (Silvy et al., 2012). However, the longevity of these devices and markings not only allows for long-term monitoring without recapture (Silvy et al., 2012) but also makes them cost-effective options for researchers. For these reasons, various tracking and monitoring techniques are used as valuable tools in conservation efforts (Graf et al., 2016).

There is extensive literature reviewing the methods for marking a wide range of amphibians, reptiles, birds and mammals (Mech & Barber, 2002; Miller et al., 2010; Silvy et al., 2012; Jewell, 2013). Given the diversity of species, there is no universally accepted list of marking techniques applicable to all animals (Silvy et al., 2012). A wide variety of factors must be considered when marking a species, including the suitability and feasibility of a marking technique for both the researcher and the animal, as well as the animal's welfare. While marking wildlife offers various benefits, the use of tracking devices and identification tags is not without

controversy (Hammerschlag et al., 2014; Cooke et al., 2017). Ethical concerns surrounding the marking of wildlife have been raised, including the potential stress and pain experienced by the animals during the process (Hammerschlag et al., 2014; Casas et al., 2015). Additionally, reports suggest that these devices may alter natural behaviour, hinder movement (Curk et al., 2021), and increase susceptibility to predators (Lennox et al., 2023).

Conflict arising from tagging animals has been documented between wildlife tourists and scientists. Instances include reports of tagged animals being harmed or harassed by the public, leading to adverse effects on their behaviour, physiology, or welfare. Additionally, tourists have expressed concerns about an excessive number of animals being tagged, the visual impact of tags on the natural experience, and alterations in animal behaviour around tourists because of tagging, such as increased avoidance of humans, impacting the wildlife viewing experience (Hammerschlag et al., 2014). These conflicts could intensify in situations where animals aggregate, such as during reproduction or at feeding grounds, particularly in areas like national parks where wildlife encounters are common. For instance, in Yellowstone National Park, USA, several species have been marked for research purposes using methods like ear-tags, collars and streamers. Craighead (1982) reported that officials in the National Park believed that visitors, mainly photographers, were offended by the sight of marked animals.

To address these concerns regarding the impact of wildlife marking, researchers are developing smaller, lighter tracking devices equipped with solar panels. This innovation aims to extend battery life, reducing the frequency of device replacement and thereby minimising the need for repeated capture and tagging of animals (Chan et al., 2016). Additionally, researchers are implementing protocols for the safe application of devices to animals, further mitigating potential adverse effects on study subjects (Wolter et al., 2018).

National parks and other wilderness areas serve as crucial research sites where wildlife is often marked with GPS tracking devices, collars, and tags for scientific studies (Petko-Seus

et al., 1985; Hammerschlag et al., 2014). These regions also attract significant numbers of tourists, who may encounter marked animals during their visits. Given that national parks and nature reserves often rely on public funding generated from visitor entrance fees, recreational activities, and hospitality services, the perceptions and opinions of the public can greatly influence stakeholders in wildlife conservation efforts (Hammerschlag et al., 2014). Consequently, it is imperative that the public understand the rationale behind marking animals for research and recognise the conservation benefits of such studies. By dispelling any misunderstandings about marking techniques and highlighting the role of research in conservation, ecotourists can be encouraged to participate in citizen science initiatives and support research efforts. Petko-Seus et al. (1985) conducted interviews with backpackers in the Great Smoky Mountains National Park in the United States to gauge public attitudes towards marking techniques employed on black bears (*Ursus americanus*) and white-tailed deer (*Odocoileus virginianus*). Participants were asked about their reactions upon encountering marked animals. Surprisingly, around 89% of backpackers did not mind seeing markers on bears, with 5-9% specifically mentioning that the markers did not harm the animals. Participants were also more likely to be upset by markings on deer when they were not informed of the purpose of the markers. This highlights the crucial role of environmental education in shaping public perceptions and fostering support for research initiatives. By providing information to the public, we can encourage greater participation in data monitoring programs and garner support for the conservation of threatened or protected species, whose survival depends heavily on informed conservation measures derived from research.

Patagial (wing) tagging has become a widely adopted method for monitoring vultures across southern Africa (Monadjem et al., 2014; Reading et al., 2015). With six species of African vultures now classified as vulnerable, endangered, or critically endangered (IUCN, 2022), rapid declines in their populations have raised conservation concerns. Through vulture

tracking initiatives, conservationists have gained insights into movement patterns, determined home ranges, and collected crucial data on reproduction, survival, and mortality (Kendall & Virani, 2012; Reading et al., 2015). These data are essential for effective vulture conservation efforts.

Vultures, whether captive-bred, rehabilitated, or wild, can be fitted with patagial tags displaying unique identification codes. These codes, along with species identification, age estimates, and body size measurements, are recorded in a central database. When a tagged vulture is sighted, observers can report the ID code, species, and location, adding valuable information to the database (VulPro, n.d.). Similarly, reports of dead vultures and suspected causes of death contribute to understanding mortality factors (pers. obs.).

Patagial tagging offers a cost-effective and efficient means of vulture monitoring (SANParks, 2007). Researchers benefit from the ease of data collection as they do not need to be physically present in the field to gather information. Sightings of tagged vultures are commonly reported by various stakeholders, including members of the public, such as tourists, park rangers, field guides, and photographers (Santangeli et al., 2020). Their contributions significantly bolster the resighting databases utilised in vulture conservation research efforts.

However, research conducted by Curk et al. (2021) revealed concerning findings regarding Cape Vultures (*Gyps coprotheres*) fitted with patagial tags. These vultures were observed to exhibit reduced flight activity, flying at slower speeds and covering shorter distances compared with individuals fitted with leg rings. Notably, the study did not account for the age of the vultures, despite known variations in behaviour and movement influenced by age and experience (Krüger, 2014; Reading, 2020). Furthermore, the study subjects were initially admitted to a rehabilitation centre because of minor injuries, potentially influencing their flight behaviour on an individual basis. Curk et al. (2021) did not consider factors such as weight, overall health, or body condition, which could also impact flight performance.

Additionally, the long-term effects of altered flight behaviour on vulture fitness and survival were not assessed post-study, leaving uncertainties about the implications of these findings. These results raise ethical concerns regarding the use of patagial tags for vulture monitoring, however, further research is warranted to comprehensively evaluate the implications of patagial tagging on vulture behaviour and welfare. Nonetheless, given the significant number of tagged vultures in South Africa, it is important to utilise the available data and actively promote public participation in reporting sightings.

Among researchers, it is acknowledged that tracking and marking devices facilitate the study of wild animals, offering valuable insights into their behaviour and ecology while minimising disturbance (Curk et al., 2021). However, there is a notable gap in our understanding of public perceptions regarding the marking of wildlife for research purposes. Negative attitudes towards wildlife marking could lead to reluctance to participate in citizen science programs and support vital research initiatives. Specifically, in the context of vulture patagial tags, negative public opinion may discourage the reporting of sightings, hindering the effectiveness of vulture monitoring efforts.

International tourists, locals, field guides, wildlife photographers, and conservation-based staff were selected to be interviewed in this study. These stakeholder groups were chosen because of their direct interactions with marked animals, reflecting a range of perspectives. Tourists play a key role in the ecotourism industry, which in turn is important in South Africa's economy (Lindsey et al., 2007), and so tourists may influence conservation funding and policies based on their encounters with marked animals. Local people living in communities that border national parks often coexist with wildlife (Anthony, 2007; Lagendijk & Gusset, 2008), and their attitudes towards tagging may reflect broader communities' sentiments. Field guides can shape visitor perceptions through their narratives and explanations (Randall & Rollins, 2009), influencing tourists' opinions of tagging, while wildlife photographers offer

perspectives on the aesthetic impact of tagging on wildlife imagery (Petko-Seus et al., 1985). Conservation professionals possess expert knowledge and ethical considerations regarding wildlife management practices (Bruskotter et al., 2019). By comprehensively evaluating stakeholder perceptions, we can tailor conservation strategies, enhance public engagement, and ensure the long-term sustainability of wildlife populations and their habitats. Recognising the crucial role of public engagement in tagging initiatives, it is imperative to raise public awareness about the significance of marking wildlife and the process of effectively reporting sightings. By gaining insights into public opinion and knowledge, we aim to identify areas for targeted education efforts and provide accurate information on the conservation value of tagging and marking wild animals. Therefore, our research sought to gain an understanding of the public perceptions of patagial tags and other marking techniques used for research purposes. We hypothesised that the study would reveal a spectrum of opinions among stakeholders, and we predicted that the better-informed stakeholder groups (e.g., conservation practitioners) would support wildlife marking techniques more because of the conservation benefits they provide. We also predicted that some stakeholder groups would report concerns about wildlife marking techniques, because of their perceived impacts on wildlife behaviour and welfare.

3.3 Methods

3.3.1 Ethical considerations

Ethical approval for this research project was granted by the Humanities and Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal (UKZN). The reference number for this approval is HSSREC/00003896/2022. Ethics approval was obtained prior to the commencement of the study, and all ethical guidelines and procedures outlined by the HSSREC were strictly adhered to, ensuring the protection of participants' rights and

confidentiality throughout the research process. The research project was conducted under SANParks Research Permit SS1124, and a Limpopo Economic Development, Environment & Tourism permit (ZA/LP/116483).

3.3.2 Study area

The in-person interviews took place in the Kruger National Park. This region of South Africa is home to a huge variety of wildlife, many of which are currently critically endangered (IUCN, 2022). In 2022/2023, the number of visitors to the Kruger National Park reached almost 5 million (SANParks, 2023). Given the rich biodiversity and the high influx of tourists visiting the area, the Kruger National Park and its surroundings present an ideal setting for surveying people's perceptions of marked animals. Locals and international tourists, wildlife photographers, field guides, rangers and other park staff who chose to participate in the study were interviewed by EL at the main rest camps and picnic sites throughout the Kruger National Park (Figure 3.1).

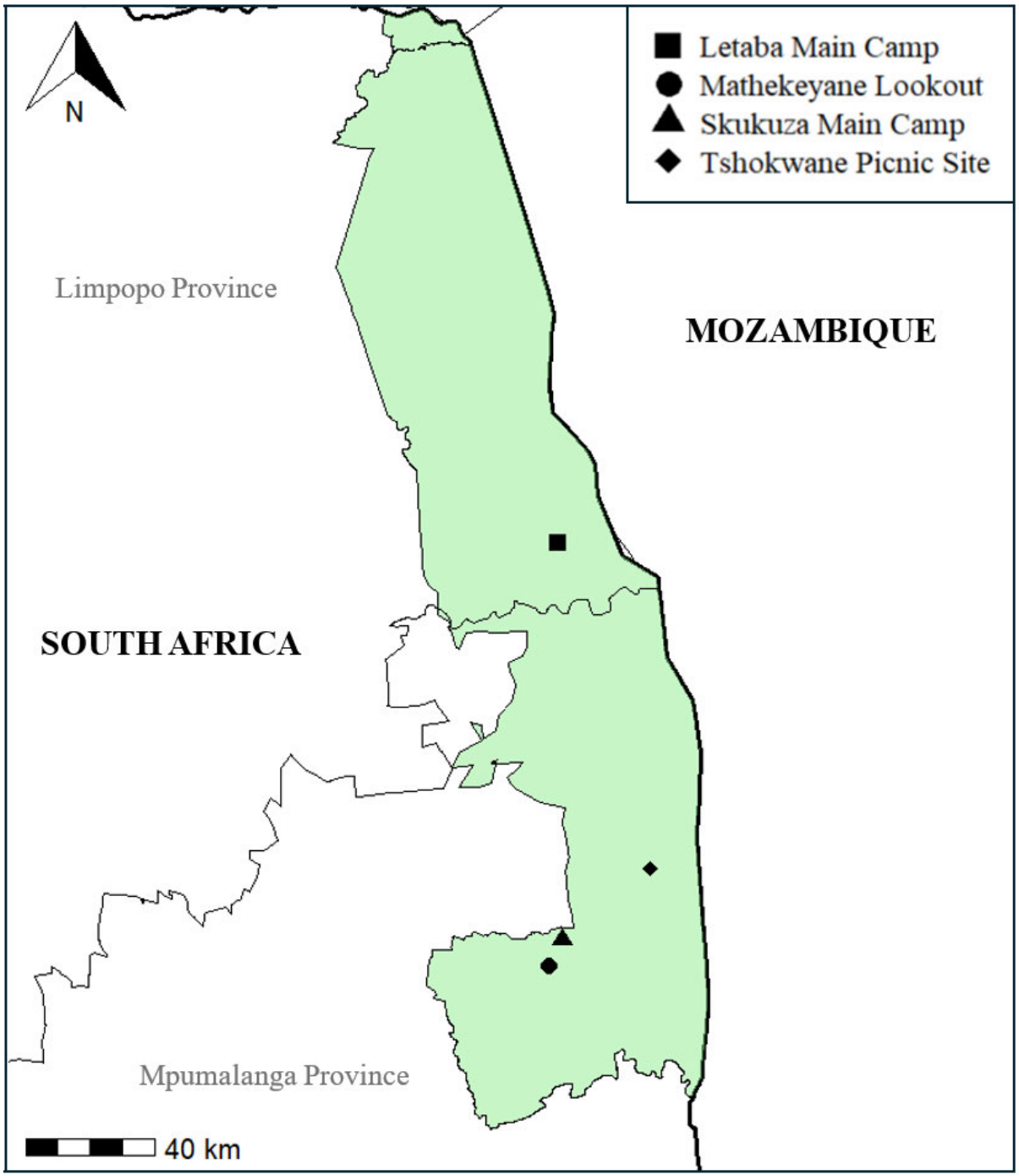


Figure 3.1: Map of Kruger National Park in South Africa. Questionnaire sites are denoted by different shapes, representing various locations within the park: Letaba Main Camp (square), Mathekeyane Lookout (circle), Skukuza Main Camp (triangle) and Tshokwane Picnic Site (diamond).

3.3.3 Interview structure

Pilot Questionnaire

Pilot interviews were held at Letaba Main Camp in Kruger National Park on the 25th February 2023, and served as the initial phase of data collection to refine the questionnaire for the main study (Supplementary Information Questionnaire S3.1). These pilot interviews involved a small sample of 10 participants, including representatives from each stakeholder group: locals, international tourists, wildlife photographers, field guides, and conservation-based staff. These interviews were conducted in a conversational manner, utilising semi-structured questions to foster a deeper understanding of participants' perspectives. The objectives of the pilot interviews were to assess the clarity and comprehensibility of the questions, identify any ambiguities or potential biases, and refine the overall structure and flow of the questionnaire. Insights gained from these initial interviews were instrumental in refining and structuring the final questionnaires to effectively engage each stakeholder group. Consequently, the structured questionnaires exhibited slight variations in language and content tailored to the specific characteristics of each group.

Structured interviews

Before conducting the in-person interviews, we did trials to ensure the questions were clearly worded. The questionnaire was conducted in person within the Kruger National Park during October 2023 and was available online from January to March 2024. The questions used in the online questionnaire and in-person interviews were the same within each stakeholder group (Supplementary Information Questionnaire S3.2). The questionnaires were predominantly comprised of open-ended questions, and photographs were used to elicit the participants' thoughts, feelings, and perspectives regarding the use of monitoring devices on wildlife for research purposes. The questionnaires were developed using SurveyMonkey (SurveyMonkey

Inc., San Mateo, California, USA, http://www.surveymonkey.com). The questionnaire was distributed online through various platforms, including the South African National Parks Facebook® page for Kruger National Park, as well as other Kruger National Park-related Facebook® pages, and on X (Twitter)®. Additionally, it was shared in Facebook® groups of towns surrounding Kruger National Park. Facebook was selected as our primary platform due to its status as the most frequently used social media across all age groups in South Africa (Budree et al., 2019), and the SANParks' official Facebook® group, with over 200,000 members at the time of the study, provided a substantial reach to a diverse audience.

3.3.4 Research questions

The study aimed to answer six primary research questions through interviews conducted among various stakeholder groups. These questions were as follows:

1) What knowledge does the public have of different marking techniques and devices?

2) What is the public opinion of marking animals using different techniques for research and monitoring purposes?

3) What does the public know about vultures?

4) What does the public know about vulture conservation?

5) What is the public opinion of tagging vultures with patagial tags?

6) Do members of the public know how to report sightings of tagged vultures?

These questions formed the basis of the interview structure and were designed to provide insights into public attitudes, knowledge, and behaviours concerning wildlife marking and vulture conservation efforts.

3.3.5 Data analyses

Our data analysis process involved systematically examining the qualitative responses gathered from the structured questionnaires. We began by categorising the responses based on recurring topics and themes to capture the breadth of participant perspectives. To achieve this, we conducted a comprehensive text analysis, employing several qualitative techniques. We started with word repetition analysis to identify frequently occurring words and highlight key terms. This was followed by contextual analysis, where we examined how these terms were used in different contexts to understand their significance and meaning. Using these insights, we applied the cutting and sorting technique, which involved highlighting relevant phrases and then sorting these phrases into categories. This process facilitated the development of themes by grouping similar concepts together. Finally, we performed thematic identification by grouping similar responses and recognising overarching themes based on the patterns observed. This methodical approach, informed by established qualitative methods (Ryan & Bernard, 2000), supports the rigorous categorisation and analysis of qualitative data. This process enabled a nuanced exploration of participants' opinions and knowledge regarding the use of monitoring devices on wildlife for research purposes, as well as their broader attitudes, perceptions, and experiences. Descriptive statistics were used to quantify the distribution of responses across different categories. This approach facilitated a comprehensive exploration of participants' perspectives, allowing for the extraction of meaningful insights and the derivation of conclusions from the data. Additionally, we used Fisher's exact tests to compare the mean counts of responses across participant groups, followed by pairwise comparisons for a more detailed analysis. Fisher's exact test was chosen because of its robustness when dealing with smaller sample sizes or expected frequencies, where the chi-squared test assumptions may not be met. Furthermore, we employed analysis of variance (ANOVA) followed by Tukey's post-

hoc test to examine differences in participant knowledge of vulture species among multiple participant groups.

3.4 Results

In total, we conducted 207 interviews, including 35 conservation staff, 25 field guides, 79 locals, 36 international tourists, and 32 wildlife photographers, to gather insights into public perceptions of wildlife marking techniques and vulture conservation. Of these, 93 interviews were conducted in person at various camps and picnic spots throughout the Kruger National Park. Additionally, we received 114 completed responses via the online questionnaire. These responses provided a comprehensive dataset for our examination of participant attitudes and opinions regarding the use of monitoring devices for wildlife and vulture conservation efforts.

3.4.1 Public knowledge of marking techniques and devices used in wildlife research and conservation

In our questionnaire, we asked participants if they had observed a marked wild animal to gauge public awareness of marking techniques used for wildlife research or conservation. There was a significant difference between the stakeholder groups (Fisher's Exact Test, $p < 0.05$). The results showed that 100% of participants working in a conservation-based career ($n = 35$), or as professional field guides ($n = 25$) and wildlife photographers ($n = 32$) had encountered marked wildlife. Ninety-four percent ($n = 34$) of international tourists and 84% ($n = 66$) of locals reported having seen marked animals. Locals had observed marked wild animals less than conservation staff ($p < 0.05$, odds ratio = 0, 95% CI [0.00, 0.67]), field guides ($p < 0.05$, odds ratio = 0, 95% CI [0.00, 0.95]) and wildlife photographers ($p < 0.05$, odds ratio = 0, 95% CI [0.00, 0.73]).

Among the various marking methods and species encountered by participants, certain trends emerged regarding the most commonly observed ones (Table 3.1). Tracking collars were notably prevalent across several species, including lions (*Panthera leo*), African wild dogs (*Lycaon pictus*), cheetahs (*Acinonyx jubatus*), leopards (*Panthera pardus*) and African elephants (*Loxodonta africana*). Various vulture and eagle species, and Southern Ground Hornbills (*Bucorvus leadbeateri*) were seen with patagial tags, leg rings and satellite harnesses. Ungulate species were often seen with ear-tags and ear-notches. Less frequently mentioned, but still notable, were wildlife species seen with brandings or tattoos (Table 3.1).

Table 3.1: Number of interview participants observing various wildlife marking methods and the species observed. These results are from in-person interviews conducted in the Kruger National Park, South Africa (n = 93), as well as an online questionnaire (n = 114). The species are listed in descending order based on the number of times they were sighted with a marking method. The order begins with mammals, categorised into carnivores, omnivores, and herbivores, followed by birds, then fish, and finally reptiles.

Species	Marking Method												
	Tracking collar	Patagial tag	Leg ring	GPS harness	Ear tag	Ear notch	Branding	Microchip in horn	Tattoo	GPS ear tag	GPS device	Fin tag	Total
Wild dog (*Lycaon pictus*)	116												**116**
Lion (*Panthera leo*)	90						4						**94**
Cheetah (*Acinonyx jubatus*)	53												**53**
Leopard (*Panthera pardus*)	30												**30**
Spotted hyena (*Crocuta crocuta*)	10												**10**
African wild Cat (*Felis lybica*)	2												**2**
Seal (Family: *Phocidae*)	1										1		**2**
Wolf (Family: *Canidae*)	1												**1**
Chacma Baboon (*Papio ursinus*)	1												**1**
Elephant (*Loxodonta africana*)	60					4							**64**
Rhino (Family: *Rhinocerotidae*)	24				6	4		4		1			**39**

Buffalo (*Syncerus caffer*)	5				15		2						**22**
Sable antelope (*Hippotragus niger*)					4								**4**
Kudu (*Tragelaphus strepsiceros*)					3								**3**
Giraffe (*Giraffa camelopardalis*)	1												**1**
Impala (*Aepyceros melampus*)	1												**1**
Plains game (Family: *Bovidae*)	1				3								**4**
Southern Ground Hornbill (*Bucorvus leadbeateri*)		4	11						2				**17**
Vulture (Family: *Accipitridae*)		57	9	19									**85**
Bird (Class: *Aves*)		10	33	4									**47**
Eagle (Family: *Accipitridae*)			3										**3**
Martial Eagle (*Polemaetus bellicosus*)			2	1									**3**
Marabou Stork (*Leptoptilos crumenifer*)		1											**1**
Fish (Subphylum: *Vertebrata*)												1	**1**
Sea Turtle (Family: *Cheloniidae*)											1		**1**
Total	**396**	**72**	**58**	**24**	**31**	**8**	**6**	**4**	**2**	**1**	**2**	**1**	

Table 3.2: Participants' (n = 207) responses on reasons for marking wild animals. Here, we present the various reasons provided by participants for why wildlife might be marked using a marking method.

Purpose of marking methods		Conservation staff (%)	Field guides (%)	International tourists (%)	Locals (%)	Wildlife photographers (%)	Total (n)
Tracking and Monitoring	Tracking movements	57 (n = 20)	44 (n = 11)	56 (n = 20)	65 (n = 51)	75 (n = 24)	126
	General monitoring	20 (n = 7)	16 (n = 4)	-	14 (n = 11)	16 (n = 5)	27
	Monitoring health	-	8 (n = 2)	11 (n = 4)	14 (n = 11)	16 (n = 5)	22
	Monitoring populations	3 (n = 1)	-	11 (n = 4)	9 (n = 7)	9 (n = 3)	15
	Identification	-	-	3 (n = 1)	3 (n = 2)	3 (n = 1)	4
Research	Ecological research	91 (n = 32)	96 (n = 24)	44 (n = 16)	38 (n = 30)	53 (n = 17)	119
	Behavioural studies	34 (n = 12)	16 (n = 4)	19 (n = 7)	10 (n = 8)	13 (n = 4)	35
	Habitat studies	17 (n = 6)	8 (n = 2)	19 (n = 7)	18 (n = 14)	16 (n = 5)	34
	Migration studies	3 (n = 1)	8 (n = 2)	11 (n = 4)	16 (n = 13)	9 (n = 3)	23
	Breeding studies	3 (n = 1)	-	11 (n = 4)	6 (n = 5)	9 (n = 3)	13
Conservation and Management	Anti-poaching purposes	52 (n = 18)	-	22 (n = 8)	19 (n = 15)	41 (n = 13)	54

Conservation and Management (continued)	Conservation & management	9 (n = 3)	32 (n = 8)	14 (n = 5)	9 (n = 7)	9 (n = 3)	26
	Preventing human-wildlife conflict	9 (n = 3)	8 (n = 2)	3 (n = 1)	1 (n = 1)	16 (n = 5)	12
	Rehabilitation and release projects	6 (n = 2)	-	3 (n = 1)	1 (n = 1)	9 (n = 3)	7
	Captive-breeding projects	-	-	-	-	6 (n = 2)	2
	Reintroduction projects	-	-	-	-	6 (n = 2)	2
Threat Assessment	Recording mortality	6 (n = 2)	8 (n = 2)	-	-	3 (n = 1)	5
	Identifying threats	3 (n = 1)	-	-	1 (n = 1)	-	2

To assess public awareness of why wildlife is marked, participants were asked to list any reasons they knew of (Table 3.2). There was a significant association ($\chi^2 = 777.72$, df = 17, $p < 0.0001$) between the reasons participants mentioned for tagging wildlife and their respective frequencies. The most frequently mentioned reasons included tracking animals' movements, ecological research, and anti-poaching efforts. Participants also cited studies related to behaviour, habitat, and health, as well as monitoring population dynamics. Less commonly mentioned reasons included wildlife rehabilitation, reintroduction projects, and identifying threats and causes of mortality.

3.4.2 Public perception of marking wildlife for research purposes

When questioned about their emotional responses to encountering marked wild animals, the stakeholder groups had varying opinions. Among conservation staff, sentiments varied, with five individuals (14%) expressing very positive views, 17 (49%) holding positive sentiments, and a smaller proportion expressing neutrality (9%, n = 3), and negativity (9%, n = 3). Seven individuals (20%) expressed a mix of sentiments. Similarly, field guides conveyed a mixture of positive (40%, n = 10) and very positive (12%, n = 3) sentiments, with a notable portion also expressing neutral (28%, n = 7) or mixed (16%, n = 4) feelings. One field guide (4%) expressed a negative attitude towards marking wildlife. Wildlife photographers exhibited a range of sentiments, with 11 (34%) expressing positivity, two (6%) expressing very positive perceptions, and some expressing mixed (31%, n = 10), negative (6%, n = 2), or very negative (9%, n = 3) perceptions., while 13% (n = 4) expressed neutral perceptions. Locals showed relatively high positivity, with 32 (41%) expressing positive sentiment and 10 (13%) expressing very positive sentiment, although six individuals (8%) expressed negative views, and three (4%) expressed very negative emotions. Thirteen locals (17%) experienced mixed emotions, and 15 (19%) felt neutral. Finally, international tourists presented a mix of positive

and very positive sentiments (44%, n = 16 and 22%, n = 8 respectively), with some expressing neutrality (8%, n = 3) or mixed (14%, n = 5) feelings, while four individuals (11%) expressed negative emotions.

Participants were also asked to provide a reason for their answers. Among those who expressed very positive or positive sentiments, the most frequently cited reasons included 'demonstrating support for conservation efforts', 'endorsing research endeavours', and 'expressing appreciation for wildlife protection initiatives'. Respondents who indicated a neutral stance when encountering marked wild animals commonly cited an acknowledgement of the necessity for marking wildlife, curiosity about ongoing research, and a lack of strong opinion. Conversely, individuals who expressed negative or very negative emotions often expressed concerns about animal welfare, describing how 'unnatural' the marking techniques appeared, and expressed discomfort at the sight of marked wildlife. Some stated the marking methods looked "too big" or "uncomfortable", and worried about the animals getting "caught on something" by the marking method. Those with mixed emotions commonly acknowledged the necessity of marking wildlife while simultaneously expressing discomfort, viewing it as a stark reminder of the adverse impact humans have had on wildlife populations despite their overall support for research and conservation efforts using marking techniques.

When field guides were asked their feelings regarding showcasing marked wildlife to tourists, the responses varied. Some expressed very positive (16%, n = 4) and positive emotions (24%, n = 6), expressing happiness and excitement at the opportunity to discuss current conservation efforts, while others felt negative (20%, n = 5) and very negative (4%, n = 1), expressing hesitance or even nervousness. Four percent (n = 1) had mixed emotions, stating that it was dependent on the demographic of the tourists, as they claimed South African people are more accepting of marked wildlife than international tourists. A significant proportion reported feeling neutral (28%, n = 7), stating that tourists were often curious and interested in

seeing marked wildlife. They also mentioned that it largely depends on the group of tourists and whether they have positive or negative reactions to marked wildlife. For those who felt reluctant or nervous, concerns about tourists' reactions seemed prevalent, with some anticipating negative responses. Some stated that it often offended, upset, or concerned tourists to see marked wildlife, expressing discomfort with humans interfering with nature. Conversely, those who expressed excitement or enjoyment noted that tourists were often eager to learn about conservation efforts and keen to report sightings to researchers. Additionally, several participants expressed enthusiasm, highlighting the chance to educate and engage tourists in discussions about conservation. However, some participants indicated that while they were willing to explain the purpose behind the markings, they preferred to prioritise unmarked animals for guest viewing to preserve the natural ambience of the wilderness. Field guides also stated that when encountering a tagged animal, tourists often inquire about various aspects of the marking method and its implications. Common questions include inquiries about the purpose of the marking method, how it works, and whether it harms the animal. Tourists also show curiosity about the research being conducted and the reasons behind studying the specific animal. Some are interested in understanding why only one animal in a group is marked and seek information on the potential effects of the marking method on animal behaviour and mobility. Additionally, tourists inquire about who is conducting the research and what information is collected through the marking method.

When asked whether they would prefer to photograph a wild animal with or without a marking method, 28% (n = 9) of wildlife photographers expressed that they had no strong preference, citing various reasons. Some photographers highlighted that both marked and unmarked animals tell a story, with marked animals showcasing important conservation efforts. Others mentioned they would prefer unmarked animals when competing in photography competitions but were open to photographing either way otherwise. Some photographers

indicated a preference for photographing unmarked animals specifically for commercial sale photography, as they believed marked animals might appear unnatural in such contexts. However, they were willing to photograph marked animals for awareness purposes, recognising the significance of highlighting conservation efforts through photography. Six percent (n = 2) of wildlife photographers expressed a preference for photographing wild animals with marking methods, again stating that it tells a story, potentially highlighting the journey and challenges faced by the animal. Additionally, they emphasised the importance of contributing to research efforts through their photography, recognising that images of marked animals can provide valuable data and insights to researchers studying wildlife populations and behaviours. The majority of wildlife photographers, comprising 66% (n = 21), expressed a preference for photographing wild animals without any marking methods. Their reasons varied but often centred around the desire for capturing images that conveyed a sense of naturalness and wildness. Many photographers stated that marked animals appeared unnatural and indicated human intervention, which diminished the authenticity of the photograph. Interestingly, the idea of using photo editing software to easily remove marking methods from images was suggested as a compromise between wildlife photographers and researchers.

3.4.3 Public knowledge of African vultures

A large proportion of each participant group reported having observed vultures previously, with conservation staff and field guides recording the highest percentages at 100% each. Among wildlife photographers, 99% indicated previous sightings, while international tourists and locals reported slightly lower but still substantial percentages, with 94% each.

Almost all participants (n = 203) were able to correctly identify a photograph of a White-backed Vulture (*Gyps africanus*) as a species of vulture, with the exception of locals (95% accuracy, n = 75). Participants were asked to name vulture species found in southern

Africa, and the average number of species named varied significantly among the different participant groups (One-way ANOVA, $F(4, 202) = 10.81$, $p < 0.001$) (Figure 3.2). Field guides demonstrated the highest level of familiarity, identifying a mean of 5.4 out of 9 vulture species found in southern Africa. Conservation staff also showed high familiarity, naming a mean of 5 vulture species. In contrast, international tourists and locals exhibited lower familiarity, with means of 3.1 and 2.8 vulture species named, respectively. Wildlife photographers fell in between, with a mean of 4.5 vulture species named.

International tourists named significantly fewer vulture species than both conservation staff (Tukey's HSD, 95% CI [-3.35, -0.37], $p < 0.05$) and field guides (Tukey's HSD, 95% CI [-3.92, -0.66], $p < 0.001$). Similarly, locals named significantly fewer vulture species than conservation staff (Tukey's HSD, 95% CI [-3.45, -0.90], $p < 0.001$) and field guides (Tukey's HSD, 95% CI [-4.04, -1.16], $p < 0.0001$). Additionally, locals named significantly fewer vulture species than wildlife photographers (Tukey's HSD, 95% CI [0.39, 3.01], $p < 0.005$).

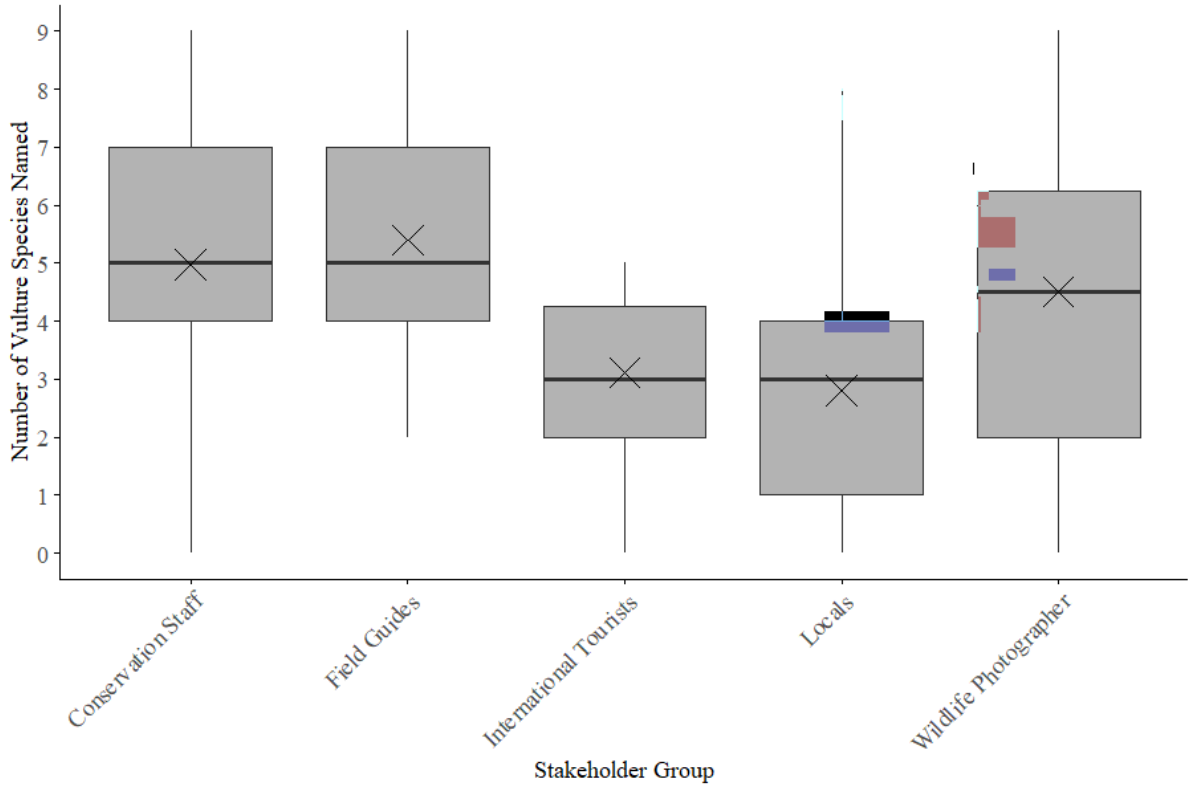


Figure 3.2: The distribution of the number of vulture species named by each participant groups. The boxplot shows the median (as the horizontal line inside each box) and the interquartile range (IQR) of the data, with whiskers extending to 1.5 times the IQR from the quartiles. Individual mean values for each stakeholder group are indicated by a black cross, representing the average number of vulture species named across responses.

Among the vulture species identified by participants, Cape Vultures were the most commonly named, mentioned by 158 out of the 207 participants (76%). White-backed Vultures followed closely, named by 148 (71%) participants, while Lappet-faced Vultures (*Torgos tracheliotos*) were identified by 126 (61%) participants. Hooded Vultures (*Necrosyrtes monachus*) and White-headed Vultures (*Trigonoceps occipitalis*) were also frequently mentioned, with 108 (52%) and 105 (51%) participants naming them, respectively. In contrast, less frequently named were the Bearded Vulture (*Gypaetus barbatus*), identified by 53 (26%) participants, and the Palm-nut Vulture (*Gypohierax angolensis*), mentioned 44 times (21%).

The Egyptian Vulture (*Neophron percnopterus*) was named by 41 (20%) participants, and Rüppell's Vulture (*Gyps rueppelli*) by 30 (14%) participants.

3.4.4 Public perception of African vultures

100% of participants agreed that vultures are an important species. All participant groups recognised vultures' importance as consumers of carrion, contributing to cleaning the environment/ecosystem and providers of essential ecosystem services. Additionally, vultures were acknowledged for their role in preventing disease spread by all participant groups. Field guides also mentioned that vultures' conspicuous circling over poached carcasses alerts rangers to crime scenes. Conservation staff emphasised the cultural and aesthetic value of vultures, as well as their importance in attracting tourism, thereby contributing to the economy.

A high level of awareness regarding the current decline in vulture populations in South Africa was evident across the participant groups. The awareness levels across participant groups did not show a statistically significant difference (Fisher's Exact Test, $p > 0.05$). Notably, 97% (n = 34) of conservation staff interviewed demonstrated awareness of this issue. Similarly, a substantial portion of field guides (88%, n = 22) were knowledgeable about the declining vulture populations. Among local participants, 84% (n = 66) indicated awareness of the situation, while 86% (n = 31) of international tourists and 91% (n = 29) of wildlife photographers were also aware of the decline in vulture populations.

Participants cited various factors as reasons for the decline in vulture populations (Table 3.3). Among the most frequently mentioned causes were poisoning, habitat loss, and traditional medicine, as identified by a significant number of participants. Specifically, poisoning was cited by 130 out of 207 (62.8%) of participants, habitat loss by 77 participants, and traditional medicine by 65 participants, underscoring their perceived significance in contributing to the decline of vulture populations. Other notable reasons included poaching (52 participants),

collisions with powerlines (28 participants), sentinel poisoning (22 participants), as well as persecution by farmers (21 participants) and members of the public (17 participants).

Table 3.3: The reasons for vulture declines as cited by participants and the number of times the reason was stated by participants. Reasons for decline are listed in descending order of frequency in which they were reported.

Reason for decline	**Frequency**
Poisoning	130
Habitat loss	77
Traditional medicine	65
Poaching	52
Collisions with powerlines	28
Sentinel poisoning	22
Persecution by farmers	21
Persecution by the public	17
Illegal trade	12
Climate change	10
Lack of food availability	8
Secondary poisoning	5
Pesticide toxicity	5
Collisions with wind turbines	5
Disease	3
Drowning in reservoirs	3
Lead toxicity	2
Predation	2
Collisions with infrastructure	2
Anthropogenic threats	1
Breeding failure	1
Nest disturbance	1
Vehicle collisions	1

3.4.5 Public perception of marking African vultures with patagial tags

An analysis of participants' emotions towards viewing vultures with patagial tags revealed varying responses across different groups. Field guides exhibited predominantly positive emotions, with 28% (n = 7) expressing very positive feelings and 44% (n = 11) expressing positive feelings. Additionally, 8% (n = 2) reported mixed sentiments, while 20% (n = 5) remained neutral, and none reported negative sentiments. International tourists showed overwhelmingly positive reactions, with 58% (n = 21) feeling very positive and 31% (n = 11) expressing positive emotions. The remaining 11% (n = 4) felt neutral towards observing vultures with patagial tags. Locals also demonstrated mainly positive responses, with 51% (n = 40) feeling very positive and 21% (n = 17) feeling positive. Twenty percent (n = 16) felt neutral, however, 8% (n = 6) reported negative emotions. Wildlife photographers expressed a mix of emotions, with 22% (n = 7) feeling very positive, 31% (n = 10) feeling positive, 34% (n = 11) feeling neutral, and 13% (n = 4) feeling negative. Conservation staff similarly exhibited positive sentiments, with 37% (n = 13) feeling very positive, 52% (n = 18) positive, and 11% (n = 4) remaining neutral. No participants in any group reported very negative feelings, highlighting a generally favourable attitude towards encountering vultures with patagial tags among the surveyed groups.

Nine field guides reported instances where they encountered patagial tagged vultures while guiding tourists. In these encounters, the guides noted a predominantly positive response from their guests, who displayed curiosity and interest in the tags. However, one of these guides mentioned that their guests expressed concern for the welfare of the vultures upon seeing the tags.

When asked whether they would prefer to photograph a vulture with or without a patagial tag, 16% (n = 5) of wildlife photographers expressed a preference for capturing images of vultures with patagial tags. Many photographers highlighted that photographing tagged

vultures allows them to spread awareness about conservation. They emphasised the role of photography in highlighting the impact of human activities on wildlife. On the other hand, 44% (n = 14) of wildlife photographers indicated a preference for photographing vultures without patagial tags. They expressed concerns about the aesthetic impact of patagial tags, noting that they detract from the natural appearance of the vulture and create an unnatural visual element in the photograph. Some photographers even found patagial tags visually unappealing or even painful-looking. Forty-one percent (n = 13) of wildlife photographers expressed their willingness to photograph either patagial tagged or non-patagial-tagged vultures. They emphasised that both scenarios offer storytelling opportunities and convey a unique narrative. Additionally, several photographers highlighted the importance of contributing to research, indicating that photographing both patagial-tagged and non-patagial-tagged vultures play a role in advancing scientific knowledge. Moreover, they mentioned encountering both patagial-tagged and non-patagial-tagged vultures together at a carcass, where this juxtaposition could be leveraged to spread awareness about vulture conservation efforts through photography, while maintaining a natural context. Furthermore, some photographers cited the ease of editing images with photo editing software as a factor influencing their decision to photograph a patagial tagged vulture.

Participants were asked to provide reasons for the patagial-tagging of vultures. This resulted in a range of responses that varied significantly in frequency ($\chi^2 = 475.95$, df = 18, $p < 0.0001$) (Table 3.4). While tracking movements, ecological research, and conservation and management were commonly cited reasons, participants also frequently mentioned rehabilitation and release projects. Less frequently mentioned reasons included monitoring lifespan, behavioural studies, and identifying mass poisoning events.

Table 3.4: Participants' responses on reasons for wing-tagging vultures.

Reason for wing-tagging vultures	Conservation staff (%)	Field guides (%)	Locals (%)	International tourists (%)	Wildlife photographers (%)
Tracking movements	51 (n = 18)	48 (n = 12)	54 (n = 43)	58 (n = 21)	44 (n = 14)
Ecological research	34 (n = 12)	48 (n = 12)	18 (n = 14)	6 (n = 2)	19 (n = 6)
Conservation and management	37 (n = 13)	40 (n = 10)	10 (n = 8)	6 (n = 2)	16 (n = 5)
Identification	29 (n = 10)	44 (n = 11)	5 (n = 4)	11 (n = 4)	22 (n = 7)
Rehabilitation and release projects	34 (n = 12)	36 (n = 9)	8 (n = 6)	3 (n = 1)	16 (n = 5)
Monitoring populations	11 (n = 4)	8 (n = 2)	18 (n = 14)	28 (n = 10)	6 (n = 2)
General monitoring	14 (n = 5)	4 (n = 1)	8 (n = 6)	8 (n = 3)	25 (n = 8)
Habitat studies	6 (n = 2)	-	10 (n = 8)	17 (n = 6)	19 (n = 6)
Monitoring health	-	-	9 (n = 7)	17 (n = 6)	9 (n = 3)
Anti-poaching purposes	17 (n = 6)	8 (n = 2)	5 (n = 4)	8 (n = 3)	3 (n = 1)
Resighting database	6 (n = 2)	20 (n = 5)	6 (n = 5)	-	-
Migration studies	-	4 (n = 1)	8 (n = 6)	-	6 (n = 2)
Identifying threats	3 (n = 1)	8 (n = 2)	4 (n = 3)	6 (n = 2)	-
Monitoring lifespan	6 (n = 2)	-	1 (n = 1)	8 (n = 3)	3 (n = 1)
Behavioural studies	3 (n = 1)	4 (n = 1)	3 (n = 2)	3 (n = 1)	3 (n = 1)
Monitoring survival rate	9 (n = 3)	4 (n = 1)	-	-	6 (n = 2)

Reporting mortality to vulture organisations	-	-	5 (n = 4)	-	6 (n = 2)
Breeding studies	6 (n = 2)	-	3 (n = 2)	-	6 (n = 2)
Identifying mass poisoning events	3 (n = 1)	-	-	-	3 (n = 1)

The questionnaire provided information on the reasons for tagging vultures (Supplementary Information Questionnaire S3.2, Q21). After this information was shared, all participant groups unanimously agreed on the importance of patagial-tagging vultures. This agreement was consistent across conservation staff, field guides, international tourists, and wildlife photographers, with 100% agreement observed in each of these groups. Additionally, nearly all locals, 99%, also agreed the patagial-tagging of vultures is important. This collective consensus reflects a shared understanding among various stakeholders regarding the importance of patagial-tagging in vulture conservation efforts.

All participant groups, including conservation staff, field guides, international tourists, locals, and wildlife photographers, unanimously expressed their willingness to report sightings of patagial-tagged vultures in the future, with 100% agreement across the board.

3.4.6 Awareness and participation in reporting patagial-tagged vultures

The study findings revealed varying levels of interaction and reporting of patagial-tagged vultures across participant groups, corresponding to their awareness of reporting procedures. There was a significant positive relationship between participant awareness of reporting procedures and reporting rate (Fisher's Exact Test, $p < 0.0001$). Field guides demonstrated a high engagement level, with 84% (n = 21) reporting having seen vultures with patagial tags, reflecting their strong awareness of the necessity to report these sightings (84%, n = 21). Seventy-one percent (n = 15) of those who had seen tagged vultures had reported the sighting to the relevant organisations. Similarly, conservation staff showed a high awareness, with 86%

(n = 30) having seen tagged vultures, aligning with their high knowledge (80%, n = 28) of reporting requirements, although the reporting rate was comparatively lower at 63% (n = 22). In contrast, local participants exhibited lower engagement, with only 14% (n = 3) reporting sightings out of the 27% (n = 21) who had observed patagial-tagged vultures, reflecting their limited awareness (32%, n = 25) of reporting procedures. International tourists displayed moderate engagement, with 50% (n = 18) observing patagial-tagged vultures but a relatively low reporting rate of 17% (n = 3), consistent with their limited awareness (31%, n = 11) of reporting requirements. Wildlife photographers demonstrated a relatively high sighting rate of 56% (n = 18), with 44% (n = 14) aware of the need to report sightings, yet only 28% (n = 9) of those who had seen a tagged vulture, actually reported it.

3.4.7 Public recommendations to increase participation in reporting vulture sightings

The most frequently suggested recommendations for researchers to encourage reporting of patagial-tagged vulture sightings included the placement of posters around Kruger National Park, the development of a dedicated mobile app for reporting sightings, and leveraging social media platforms for outreach. Participants also emphasised the importance of integrating information into Kruger National Park entry permits. Additionally, suggestions were made to give presentations at schools and within the national parks to raise awareness among local communities and visitors. Communicating with local farmers and placing posters in towns within vulture inhabited areas were also highlighted as effective strategies to engage stakeholders. Many participants stressed the importance of providing feedback to reporters as a way of encouraging them to report sightings again. These recommendations give researchers a number of methods to use to engage stakeholder participation in vulture conservation efforts.

3.5 Discussion

In this study, we investigated public awareness and perception of wildlife marking techniques, particularly focusing on the patagial tagging of African vultures. We examined the knowledge and attitudes of various stakeholder groups, including conservation professionals, field guides, wildlife photographers, international tourists, and locals. Our findings revealed a high level of public awareness and support for these techniques, especially among conservation professionals, field guides, and wildlife photographers. As we predicted, the issue of animal welfare was mentioned on numerous occasions by participants. Overall, public perception of marking African vultures with wing-tags was positive, with strong willingness across all groups to report sightings of tagged birds, highlighting the potential for enhanced engagement in vulture conservation initiatives.

3.5.1 Public knowledge of marking techniques and devices used in wildlife research and conservation

The results of this study reveal a high level of public awareness regarding marking techniques employed in wildlife research and conservation efforts. Across participant groups, including conservation-based professionals, field guides, wildlife photographers, international tourists, and locals, encounters with marked wildlife were common. Specifically, 100% of conservation-based professionals (n = 35), field guides (n = 25), and wildlife photographers (n = 32) reported sightings of marked animals, with substantial proportions of international tourists (94%, n = 34) and locals (84%, n = 66) also documenting sightings of marked wildlife. These findings demonstrate the strong awareness of marking techniques commonly used in wildlife research and conservation efforts among the stakeholder groups.

There was a notable familiarity among the public with specific marking techniques. Tracking collars, commonly seen by the respondents on lions, wild dogs, elephants, and other

prominent species, as well as patagial tags frequently observed on birds such as vultures and eagles, were recognised by many participants (Table 3.1). Methods like ear-tags on ungulates such as rhinos, buffaloes and antelope were less familiar but still acknowledged by some respondents. This broad awareness across various marking methods is encouraging, as it suggests the public is well informed and capable of understanding the diverse approaches used in wildlife research and conservation efforts. A lack of knowledge regarding wildlife marking can result in stakeholders disagreeing with marking wildlife (Wilson & McMahon, 2006). Awareness and knowledge of conservation issues not only strengthen public support but also encourage deeper engagement with conservation initiatives (Bremner & Park, 2007; Hammerschlag et al., 2014; O'Bryhim & Parsons, 2015), highlighting the importance of ongoing education and outreach efforts.

This study revealed valuable insights into the public awareness of the purpose of marking wildlife. Tracking movements was one of the most frequently cited reasons across participant groups, indicating a widespread understanding of the importance of tracking individual animals, and groups, for research and conservation purposes. Additionally, anti-poaching efforts were prominently mentioned, highlighting the recognition of marking wildlife as a crucial method in combating illegal activities and protecting vulnerable species (Kragt et al., 2020; Sarkar et al., 2022). By enabling rangers to track at-risk species and monitor their movements, marking techniques, such as tracking devices, may play a vital role in safeguarding them (Banzi, 2014). Similarly, ecological research was also frequently mentioned as a reason for marking wildlife, reflecting the acknowledgement of the role of marked wildlife in advancing scientific understanding of species and ecosystems. The understanding demonstrated by participants regarding the purpose of marking wildlife is highly encouraging and highlights the potential for positive relationships between the public and researchers, creating a positive perception of marking wildlife (Hammerschlag et al., 2014).

However, our study also revealed a gap in awareness regarding certain important purposes of marking wildlife. Less frequently mentioned were purposes such as wildlife rehabilitation and reintroduction projects, as well as identifying threats and causes of mortality. Despite their significance in wildlife management and conservation (Watson & Watson, 2015), participants did not acknowledge these purposes as prominently. This highlights that there is still a need for more public education to increase awareness of the diverse roles that marking techniques play in conservation by assisting researchers in monitoring reintroduced individuals and groups (Rio-Maior et al., 2016; Myers & Young, 2018; Goldenberg et al., 2021). By addressing these knowledge gaps through outreach activities, and environmental awareness drives, for example, through talks given to wildlife rehabilitation facility visitors, researchers can better engage the public and gain support for conservation efforts (Siemer et al., 1991; Meadows, 2011).

3.5.2 Public perception of marking wildlife for research purposes

Understanding the public perception of marking wildlife is essential for increasing support and engagement in conservation efforts (Petko-Seus et al., 1985; Hammerschlag et al., 2014). Our study delved into the attitudes and feelings of participants towards encountering marked wild animals, revealing both positive sentiments and notable concerns.

The majority of respondents across all participant groups expressed positive feelings when encountering marked wildlife. This positivity stemmed from a sense of support for conservation efforts and an appreciation for the role of marking techniques in wildlife protection and research. The majority of positive responses to encountering marked wildlife are promising, indicating strong public support for conservation efforts and research initiatives. This widespread endorsement signifies a growing support for wildlife monitoring and management practices. However, alongside these positive attitudes, concerns were also raised.

Among the concerns expressed by participants, animal welfare emerged as a prominent issue. Some individuals voiced discomfort and unease at the sight of marked wildlife, suggesting that the devices appeared too big or uncomfortable for the animals. Additionally, participants with mixed emotions highlighted their support for research and conservation while harbouring similar reservations regarding animal welfare. We therefore recommend prioritising educating the public on the strict protocols followed when marking wildlife (Botha, 2007; Wolter et al., 2018; Andrews et al., 2019). This should help address concerns and build trust by highlighting that trained experts conduct these procedures to minimise animal discomfort. Although, in recent years, tracking devices have become smaller and lighter (Chan et al., 2016; Dore et al., 2020), work should still focus on refining marking techniques to make them less intrusive. Implementing these steps should strengthen public support for wildlife research and conservation while safeguarding animal welfare.

Insights from field guides provided valuable perspectives on the challenges of showcasing marked wildlife to tourists. While some guides expressed enthusiasm for discussing conservation efforts and educating guests, others voiced concerns about negative reactions and visitor discomfort. This highlights the need for effective communication strategies to navigate tourist interactions and create understanding and appreciation for marking techniques (Hammerschlag et al., 2014). Such strategies could include holding workshops to train guides to engage tourists in open and constructive dialogues about conservation efforts and the role of marking techniques, which could help dispel misconceptions and alleviate concerns. Guides should encourage tourists to ask questions and facilitate discussions during wildlife encounters to further enhance their understanding of the importance of marking wildlife for research and conservation purposes (Hammerschlag et al., 2014).

The perspectives of wildlife photographers offer valuable insights into the diverse viewpoints within the community. While some photographers acknowledged the storytelling

potential of capturing images of marked animals and their role in supporting research efforts, the majority preferred focusing on unmarked wildlife to convey a sense of naturalness and authenticity in their photography. However, it's worth noting that many photographers expressed the belief that their photography could contribute to spreading awareness of conservation efforts. They highlighted their ability to share images with researchers to assist in data collection and research, emphasising the collaborative role photographers could play in wildlife conservation. Researchers could engage photographers by explaining the value of photographing marked animals and sharing these images for research purposes, thereby creating broader acceptance and support for marking techniques in conservation initiatives (Hanisch et al., 2019).

Continuous education and outreach efforts are vital for improving public understanding and acceptance of marking techniques in wildlife conservation (Hammerschlag et al., 2014). Proactive measures, such as detailed explanations of marking purposes and the steps taken to ensure minimal impact on wildlife, can address concerns and enhance transparency. Encouraging public engagement in wildlife research initiatives creates a sense of responsibility towards conservation efforts (Maund et al., 2020). Given the rapid pace of technological innovation in wildlife research and conservation, there is optimism that future advancements may lead to the development of less invasive marking techniques that address the ethical and aesthetic concerns without compromising data collection (Chan et al., 2016; Dore et al., 2020). To further enhance public perception, researchers could collaborate with stakeholders to ensure inclusive decision-making processes that balance conservation needs and animal welfare considerations. Overall, by prioritising ongoing education and outreach initiatives and implementing transparent communication strategies, we can foster greater support and engagement in conservation efforts, ultimately contributing to the protection of wildlife and the sustainable management of natural ecosystems.

3.5.3 Public knowledge of African vultures

The participants' responses revealed varying levels of public awareness regarding different vulture species in South Africa. Cape Vultures, white-backed vultures, and lappet-faced vultures emerged as the most frequently named species, indicating a higher level of recognition of these species among the participants. This awareness is particularly crucial given the conservation statuses of these species; Cape Vultures are vulnerable, White-backed Vultures are critically endangered, and lappet-faced vultures are endangered (IUCN, 2022).

However, Hooded Vultures and White-headed Vultures were mentioned less frequently in the responses, indicating lower awareness of these species among participants. Given their critical endangered status (IUCN, 2022), it is crucial to raise awareness about these vulture species to garner public support and funding for their conservation efforts (Wilson & Tisdell, 2005).

Additionally, species, including the Bearded Vulture, Egyptian Vulture, Palm-nut Vulture, and Rüppell's Vulture, were even less frequently mentioned. While their conservation remains crucial (Rushworth & Chittenden, 2004; Buechley et al., 2018; Muñoz et al., 2023), their limited visibility in South Africa (IUCN, 2022) may contribute to decreased public recognition. Efforts should aim to raise awareness not only of commonly encountered vulture species but also of those that occur less commonly in South Africa. Targeted educational campaigns, community engagement programs, and collaboration with local stakeholders can play pivotal roles in increasing public awareness and understanding of all vulture species' importance and conservation needs (Cortés-Avizanda et al., 2018). Increased public engagement holds the potential to enhance the reporting of vulture sightings, strengthen monitoring programs, and garner broader support for conservation initiatives aimed at safeguarding vulture populations in South Africa.

3.5.4 Public perception of African vultures

The unanimous recognition of vultures as an important species among the stakeholder groups highlights the widespread appreciation for their ecological significance. Participants stated various reasons for their importance, including vultures' crucial role as consumers of carrion, cleaning the environment and providing essential ecosystem services. Additionally, participants stated that vultures play a crucial role in preventing disease spread, therefore safeguarding public and ecosystem health. Field guides further emphasise the significance of vultures by noting their role in alerting to poaching activity, indicating their importance beyond ecological considerations. Conservation staff stated that their presence in the ecosystem not only supports ecological balance but also enriches cultural heritage and drives economic activities through ecotourism. This acknowledgement of vultures' cultural significance and their economic value in driving ecotourism emphasises the socio-economic benefits associated with their preservation. This appreciation for vultures is an important finding as it signals a readiness among people to support conservation efforts aimed at protecting these birds (Cortés-Avizanda et al., 2018).

Importantly, this study showed a high level of public awareness concerning the current declines in vulture populations across South Africa. Participants from all stakeholder groups demonstrated a significant understanding of this pressing issue. Conservation staff exhibited the highest level of awareness, followed by wildlife photographers, field guides, international tourists and local participants. The participants identified several factors contributing to the decline of vulture populations, with poisoning, habitat loss, and the use of vulture body parts in traditional medicine being among the most frequently mentioned causes. Moreover, habitat loss emerged as a recurring concern, demonstrating the many challenges these birds face.

The use of vulture body parts in traditional medicine highlights the cultural complexities involved in vulture conservation efforts. Engaging with local communities to address cultural practices involving vulture body parts is imperative for ensuring coexistence and promoting vulture conservation. By involving local communities in conservation efforts, we can promote mutual understanding and cooperation toward the preservation of vulture populations and their habitats (Mashele et al., 2021b; Mashele et al., 2021a).

Overall, our study highlights the importance of ongoing efforts to enhance public awareness and engagement regarding vulture conservation. The participants' awareness of the threats facing vulture populations is encouraging for conservation efforts. Strengthening the public's connection with vultures through education, outreach programs, and community involvement is vital for gaining support for conservation initiatives and mitigating the diverse challenges these birds face. This increased awareness has the potential to translate into tangible support, including advocacy for policy changes, participation in citizen science projects, and financial contributions to conservation organisations (Ogada et al., 2012).

3.5.5 Public perception of marking African vultures with patagial tags

The study results provide valuable insights into public perceptions of marking African vultures with patagial tags, offering a glimpse into the diverse emotional responses across different participant groups. Overall, the majority of respondents reported positive or neutral feelings towards encountering vultures with patagial tags, indicating a level of acceptance and support for the conservation practice among the surveyed groups.

Field guides, being intimately familiar with tagging procedures and the conservation significance of patagial tags, exhibited predominantly positive emotions towards observing tagged vultures. This positive attitude demonstrates the importance of education and awareness in shaping perceptions, as informed explanations about tagging procedures can positively

influence public attitudes (Hammerschlag et al., 2014). Similarly, international tourists and locals also displayed predominantly positive reactions, suggesting potential for public engagement and support for vulture conservation initiatives. However, the study also revealed a mixed emotional response from wildlife photographers, with some expressing concerns about the aesthetic impact of patagial tags on their photographs. Addressing these concerns and promoting an understanding of the conservation value of patagial tagging among photographers may be necessary to encourage greater participation and support from this group.

Moreover, the study identified various reasons for patagial tagging vultures believed by the participants, with tracking movements and ecological research being the most commonly cited purposes. This highlights the importance of monitoring and research in understanding vulture populations and behaviours. Participants also frequently mentioned rehabilitation and release projects. This emphasis on rehabilitation and release projects stands out in comparison to responses regarding the broader purposes of wildlife tagging. The increased mention of this reason suggests a heightened awareness among participants of efforts aimed at rehabilitating and releasing vultures back into their natural habitats. Encouragingly, a proportion of wildlife photographers expressed a preference for photographing vultures with patagial tags, or the willingness to photograph either tagged or non-tagged vultures, recognising the role of photography in raising awareness about conservation issues.

Overall, the findings suggest that public awareness and support for marking African vultures with wing-tags are crucial for the success of vulture conservation initiatives. By addressing concerns, promoting understanding, and highlighting the conservation value of wing-tagging, we can create greater engagement and participation in efforts to protect these birds.

The unanimous agreement among all participant groups on the importance of patagial tagging vultures demonstrates a shared understanding and recognition of this method's value

in vulture conservation. This consensus, observed across the diverse stakeholders groups, reflects a broad societal acknowledgement of the necessity of patagial tagging to safeguard vulture populations and their ecological roles.

Moreover, the unanimous willingness of all groups to report sightings of patagial tagged vultures demonstrates a high level of public engagement and readiness to contribute to monitoring and conservation initiatives. This positive attitude towards reporting sightings reflects a collective commitment to supporting conservation efforts and aiding data collection.

Overall, these findings highlight a strong foundation of support and cooperation for vulture conservation efforts. By harnessing this shared commitment and engagement, we can work towards ensuring the long-term survival and well-being of vultures and their ecosystems.

3.5.6 Awareness and participation in reporting wing-tagged vultures

Our study results shed light on the varying levels of interaction and reporting of patagial tagged vultures among different participant groups, highlighting differences in awareness of reporting procedures. An important finding was the significant correlation between awareness of vulture sighting reporting procedures and increased reporting likelihood. This highlights the pivotal role of educational outreach initiatives focused on tagging and reporting protocols to bolster reporting rates and enhance conservation efforts. Field guides emerged as the most engaged group, with a high percentage of sightings reported and a strong awareness of the necessity to report these sightings. Their active participation highlights the importance of their role as key stakeholders in vulture conservation efforts. Conservation staff also demonstrated significant involvement in reporting sightings of patagial tagged vultures, albeit with a slightly lower reporting rate compared with field guides. Their awareness of reporting requirements indicates a promising level of engagement within the conservation community, highlighting the potential for collaboration between researchers and conservation practitioners in monitoring vulture

populations. In contrast, local participants exhibited lower engagement levels, reflecting a limited awareness of reporting procedures. To address this, researchers could spread awareness, as suggested by the participants, by giving educational presentations to local schools, meeting with farmers to discuss vulture conservation and reporting sightings of tagged vultures, as well as putting informational posters around towns in areas where vultures are present. Increasing community involvement in vulture monitoring efforts can enhance data collection and contribute to more effective conservation strategies (Rotman et al., 2012; Maund et al., 2020). Despite demonstrating a relatively high sighting rate of patagial tagged vultures, wildlife photographers exhibited a lower reporting rate, suggesting a disconnect between awareness of reporting procedures and actual reporting behaviour. Encouraging photographers to actively contribute to vulture monitoring efforts through reporting can enhance data collection and provide valuable insights into vulture movements and behaviour. While a moderate number of international tourists stated observing patagial tagged vultures, their reporting rate was relatively low, indicating a gap in awareness of reporting requirements among this group. Informational posters and educational presentations about how to report vulture sightings could be held at the main camps within South Africa's national parks to help educate tourists. Also, putting information into entry permits of national parks can help spread awareness of reporting procedures to international tourists and wildlife photographers. Efforts to improve communication and outreach to tourists visiting vulture habitats can help bridge this gap and encourage greater participation in reporting sightings.

Overall, the findings highlight the importance of raising awareness and promoting active participation in reporting sightings of patagial tagged vultures across stakeholder groups. By encouraging field guides, conservation-based staff, local communities, tourists, and wildlife photographers to report sightings, we can improve vulture monitoring efforts and contribute to the conservation of these iconic species. Additionally, targeted education and outreach

initiatives should be implemented to enhance awareness of reporting procedures and encourage active participation among all stakeholder groups.

3.5.7 Public recommendations to increase participation in reporting vulture sightings

The results revealed several key recommendations from the public aimed at enhancing the reporting of patagial-tagged vulture sightings. Among the most frequently suggested strategies were placing posters throughout Kruger National Park, developing a dedicated mobile app for reporting sightings, and utilising social media platforms for outreach purposes. These suggestions underscore the importance of leveraging technology and digital communication channels to facilitate public engagement in vulture conservation efforts (Bergman et al., 2022). Also, circulating educational materials and advertising citizen science projects has been shown to increase public participation (Lee et al., 2018).

Moreover, participants highlighted the integration of vulture sighting reporting information into Kruger National Park entry permits as a practical means to reach a broad audience of park visitors. Additionally, recommendations were made to conduct educational presentations at schools and within national parks to raise awareness among local communities and tourists alike. This approach may foster a deeper understanding of vulture conservation issues (Ballantyne, 2009; Meadows, 2011; Perdue, 2012; Hammerschlag et al., 2014).

Engagement with local farmers and placing informational posters in towns situated within vulture-inhabited areas were identified as crucial strategies to involve broader community stakeholders in conservation efforts. These efforts aim to increase awareness and foster a sense of stewardship among local populations who interact closely with vulture habitats (Lemke et al., 2010; Hammerschlag et al., 2014; Greiner, 2015).

An overarching theme from the recommendations was the importance of providing feedback to individuals who report vulture sightings. This aspect was emphasised as a means

to acknowledge and encourage continued participation in monitoring and reporting activities. Feedback and open communication channels between data contributors and project administrators are crucial for motivating participation in citizen science projects (Rotman et al., 2012; Maund et al., 2020).

The study findings provide researchers and conservationists with a comprehensive array of strategies to effectively engage stakeholders in vulture conservation initiatives. By implementing these recommendations, there is an opportunity to enhance public awareness, foster community involvement, and ultimately contribute to the preservation of vulture species within and beyond Kruger National Park.

3.6 Limitations

Several limitations were identified in this study that may affect the generalisability and interpretation of the findings. One limitation is the relatively small sample size within each stakeholder group, which may restrict the generalisability of the results to broader populations. However, it is important to note that the sample was selected purposively to target specific groups with relevant knowledge and experience, rather than aiming for a broad representation of the general population (Rust, et al., 2017; Campbell et al., 2020).

Additionally, demographic information such as age, education level, and employment status of participants was not systematically collected, which could have provided deeper insights into variations in perceptions and responses across different demographic segments. Moreover, the interviews were conducted solely in English, potentially hindering participation among individuals who are not proficient in the language. This limitation is particularly important as many community members surrounding Kruger National Park may primarily speak languages other than English. Given South Africa's multiple official languages, future

studies should consider multilingual approaches to ensure broader inclusivity and representation in study participation.

Overall, future studies should include larger and more diverse samples within each stakeholder group, gathering comprehensive demographic data, and implementing language-sensitive strategies to enhance the accessibility and representativeness of the findings.

3.7 Conclusions

Our study provides valuable insights into public knowledge, perceptions, and engagement regarding wildlife marking techniques and African vulture conservation. The findings highlight a generally high awareness of marking techniques used in wildlife research, coupled with a positive perception of their importance. However, there are gaps in understanding the specific purposes of marking wildlife, indicating the need for ongoing public education.

Our study also reveals predominantly positive attitudes towards marking African vultures with patagial tags. There were variations in engagement and reporting of patagial tagged vultures among different participant groups, highlighting the importance of increasing awareness and promoting active participation in monitoring efforts, particularly among locals, international tourists, and wildlife photographers.

In conclusion, ongoing education, outreach initiatives, and transparent communication between researchers and the public are essential for enhancing public awareness, perception, and engagement in wildlife conservation efforts. Collaboration with stakeholders is key to implementing effective conservation strategies and safeguarding vultures.

3.8 Acknowledgements

We gratefully acknowledge the support of SANParks for granting the necessary research permit (SS1124) and providing invaluable assistance throughout the study. Our heartfelt thanks

go to the camp managers at Letaba and Skukuza camps for their cooperation and support, which were crucial in facilitating our research activities. Their dedication and assistance were instrumental in the successful completion of this project. We are grateful to the University of KwaZulu-Natal (ZA) and the National Research Foundation (ZA, grant 98404) for funding. We are also grateful to the Rufford Foundation for its financial support.

3.9 References

Andrews, R. D., Baird, R. W., Calambokidis, J., Goertz, C. E., Gulland, F. M., Heide-Jorgensen, M. P., Hooker, S. K., Johnson, M., Mate, B., & Mitani, Y. (2019). Best practice guidelines for cetacean tagging. *Journal of Cetacean Research Management, 20*, 27-66.

Anthony, B. (2007). The dual nature of parks: attitudes of neighbouring communities towards Kruger National Park, South Africa. *Environmental Conservation*, *34*(3), 236-245.

Ballantyne, R., Packer, J., & Hughes, K. (2009). Tourists' support for conservation messages and sustainable management practices in wildlife tourism experiences. *Tourism Management, 30(5)*, 658-664.

Banzi, J. F. (2014). A sensor based anti-poaching system in Tanzania national parks. *International Journal of Scientific and Research Publications*, *4*(4), 1-7.

Bergman, J. N., Buxton, R. T., Lin, H.-Y., Lenda, M., Attinello, K., Hajdasz, A. C., Rivest, S. A., Tran Nguyen, T., Cooke, S. J., & Bennett, J. R. (2022). Evaluating the benefits and risks of social media for wildlife conservation. *Facets, 7(1)*, 360-397.

Botha, A. (2007). A review of colour-marking techniques used on vultures in southern Africa. *Vulture News*, *56*, 52-63.

Bremner, A., & Park, K. (2007). Public attitudes to the management of invasive non-native species in Scotland. *Biological Conservation, 139(3-4)*, 306-314.

Broekhuis, F., Madsen, E. K., Keiwua, K., & Macdonald, D. W. (2019). Using GPS collars to investigate the frequency and behavioural outcomes of intraspecific interactions among carnivores: A case study of male cheetahs in the Maasai Mara, Kenya. *PLoS One*, *14*(4), e0213910. https://doi.org/10.1371/journal.pone.0213910

Bruskotter, J. T., Vucetich, J. A., Dietsch, A., Slagle, K. M., Brooks, J. S., & Nelson, M. P. (2019). Conservationists' moral obligations toward wildlife: values and identity promote conservation conflict. *Biological Conservation, 240*, 108296. https://doi.org/10.1016/j.biocon.2019.108296

Budree, A., Fietkiewicz, K., & Lins, E. (2019). Investigating usage of social media platforms in South Africa. *The African Journal of Information Systems*, *11*(4), 314-336.

Buechley, E. R., McGrady, M. J., Çoban, E., & Şekercioğlu, Ç. H. (2018). Satellite tracking a wide-ranging endangered vulture species to target conservation actions in the Middle East and East Africa. *Biodiversity and Conservation, 27*, 2293-2310.

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: complex or simple? Research case examples. *Journal of research in Nursing*, *25*(8), 652-661.

Casas, F., Benítez-López, A., García, J. T., Martín, C. A., Viñuela, J., & Mougeot, F. (2015). Assessing the short-term effects of capture, handling and tagging of sandgrouse. *Ibis*, *157*(1), 115-124.

Chan, Y.-C., Brugge, M., Tibbitts, T. L., Dekinga, A., Porter, R., Klaassen, R. H. G., & Piersma, T. (2016). Testing an attachment method for solar-powered tracking devices on a long-distance migrating shorebird. *Journal of Ornithology*, *157*(1), 277-287.

Cooke, S. J., Nguyen, V. M., Kessel, S. T., Hussey, N. E., Young, N., & Ford, A. T. (2017). Troubling issues at the frontier of animal tracking for conservation and management. *Conservation Biology*, *31*(5), 1205-1207.

Cortés-Avizanda, A., Martín-López, B., Ceballos, O., & Pereira, H. M. (2018). Stakeholders perceptions of the endangered Egyptian vulture: Insights for conservation. *Biological Conservation*, *218*, 173-180.

Craighead, F. (1982). *Track of the Grizzly*. Random House.

Curk, T., Scacco, M., Safi, K., Wikelski, M., Fiedler, W., Kemp, R., & Wolter, K. (2021). Wing tags severely impair movement in African Cape Vultures. *Animal Biotelemetry*, *9*(1), 1-13.

Dore, K. M., Hansen, M. F., Klegarth, A. R., Fichtel, C., Koch, F., Springer, A., Kappeler, P., Parga, J. A., Humle, T., & Colin, C. (2020). Review of GPS collar deployments and performance on nonhuman primates. *Primates*, *61*, 373-387.

Goldenberg, S. Z., Hahn, N., Stacy-Dawes, J., Chege, S. M., Daballen, D., Douglas-Hamilton, I., Lendira, R. R., Lengees, M. J., Loidialo, L. S., & Omengo, F. (2021). Movement of rehabilitated African elephant calves following soft release into a wildlife sanctuary. *Frontiers in Conservation Science*, *2*, 720202. https://doi.org/10.3389/fcosc.2021.720202

Graf, P. M., Hochreiter, J., Hackländer, K., Wilson, R. P., & Rosell, F. (2016). Short-term effects of tagging on activity and movement patterns of Eurasian beavers (*Castor fiber*). *European Journal of Wildlife Research*, *62*(6), 725-736.

Greiner, R. (2015). Motivations and attitudes influence farmers' willingness to participate in biodiversity conservation contracts. *Agricultural Systems*, *137*, 154-165.

Hammerschlag, N., Cooke, S. J., Gallagher, A. J., & Godley, B. J. (2014). Considering the fate of electronic tags: interactions with stakeholders and user responsibility when encountering tagged aquatic animals. *Methods in Ecology and Evolution*, *5*(11), 1147-1153.

Hanisch, E., Johnston, R., & Longnecker, N. (2019). Cameras for conservation: wildlife photography and emotional engagement with biodiversity and nature. *Human Dimensions of Wildlife, 24(3),* 267-284.

Iredale, S. K., Nevill, C. H., & Lutz, C. K. (2010). The influence of observer presence on baboon (*Papio* spp.) and rhesus macaque (*Macaca mulatta*) behavior. *Applied Animal Behaviour Science*, *122*(1), 53-57. https://doi.org/10.1016/j.applanim.2009.11.002

IUCN. (2022). *Vultures,* IUCN Red List. https://www.iucnredlist.org/search?query=vulture&searchType=species

Jewell, Z. (2013). Effect of monitoring technique on quality of conservation science. *Conservation Biology*, *27*(3), 501-508.

Kendall, C. J., & Virani, M. Z. (2012). Assessing mortality of African vultures using wing tags and GSM-GPS transmitters. *Journal of Raptor Research*, *46*(1), 135-140.

Kragt, M. E., Hay, E., Scheufele, G., Bennett, J., & Renton, M. (2020). Predicting the effectiveness of community anti-poaching patrols for conserving threatened wildlife in the Lao PDR. *Journal of Applied Ecology*, *57*(2), 320-330.

Krüger, S., Reid, T., and Amar, A. (2014). Differential range use between age classes of southern African Bearded Vultures *Gypaetus barbatus. PLoS One*, *9*(12), e114920.

Lagendijk, D. G., & Gusset, M. (2008). Human–carnivore coexistence on communal land bordering the Greater Kruger Area, South Africa. *Environmental Management*, *42*, 971-976.

Lee, T. K., Crowston, K., Harandi, M., Østerlund, C., & Miller, G. (2018). Appealing to different motivations in a message to recruit citizen scientists: results of a field experiment. *Journal of Science Communication, 17(1),* A02. https://doi.org/10.22323/2.17010202

Lemke, A., Lindenbaum, T., Perry, W., Herbert, M., Tear, T., & Herkert, J. (2010). Effects of outreach on the awareness and adoption of conservation practices by farmers in two agricultural watersheds of the Mackinaw River, Illinois. *Journal of Soil and Water Conservation, 65(5),* 304-315.

Lennox, R. J., Dahlmo, L. S., Ford, A. T., Sortland, L. K., Vogel, E. F., & Vollset, K. W. (2023). Predation research with electronic tagging. *Wildlife Biology*, e01045. https://doi.org/10.1002/wlb3.01045

Lindsey, P. A., Alexander, R., Mills, M. G., Romañach, S., & Woodroffe, R. (2007). Wildlife viewing preferences of visitors to protected areas in South Africa: implications for the role of ecotourism in conservation. *Journal of Ecotourism*, *6*(1), 19-33.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021a). Traditional health practitioners' and other community members' perceptions of vultures in the Kruger to Canyons biosphere region, South Africa. *Journal of Raptor Research, 55(3),* 340-358.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021b). Uses of Vultures in Traditional Medicines in the Kruger to Canyons Biosphere Region, South Africa. *Journal of Raptor Research, 55(3),* 328-339.

Maund, P. R., Irvine, K. N., Lawson, B., Steadman, J., Risely, K., Cunningham, A. A., & Davies, Z. G. (2020). What motivates the masses: Understanding why people contribute to conservation citizen science projects. *Biological Conservation*, *246*, 108587. https://doi.org/10.1016/j.biocon.2020.108587

McMahon, C. R., Collier, N., Northfield, J., & Glen, F. (2011). Taking the time to assess the effects of remote sensing and tracking devices on animals. *Animal Welfare*, *20*(4), 515.

Meadows, A. (2011). Wildlife conservation education and international programmes. *The Journal of Animal and Plant Sciences, 21(2),* 305-316.

Mech, L. D., & Barber, S. M. (2002). *A critique of wildlife radio-tracking and its use in national parks*. United States Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Miller, C. S., Hebblewhite, M., Goodrich, J. M., & Miquelle, D. G. (2010). Review of research methodologies for tigers: telemetry. *Integrative Zoology*, *5*(4), 378-389.

Monadjem, A., Wolter, K., Neser, W., & Kane, A. (2014). Effect of rehabilitation on survival rates of endangered Cape vultures. *Animal Conservation, 17*(1), 52-60.

Muñoz, A.-R., Ramírez, J., & Real, R. (2023). A critically endangered African vulture starts breeding in Europe: Escaping from extinction or entering a genetic amalgamation trap? *Ardeola*, *71*(1), 131-135.

Myers, P. J., & Young, J. K. (2018). Post-release activity and habitat selection of rehabilitated black bears. *Human–Wildlife Interactions, 12,* 322–337.

O'Bryhim, J. R., & Parsons, E. (2015). Increased knowledge about sharks increases public concern about their conservation. *Marine Policy, 56,* 43-47.

Ogada, D., Keesing, F., & Virani M, Z. (2012). Dropping dead: causes and consequences of vulture population declines worldwide. *Annals of the New York Academy of Sciences, 1249(1),* 57-71.

Perdue, B. M., Stoinski, T. S., & Maple, T. L. (2012). Using Technology to Educate Zoo Visitors About Conservation. *Visitor Studies, 15(1),* 16–27.

Petko-Seus, P. A., Hastings, B. C., Hammitt, W. E., & Pelton, M. R. (1985). Public attitudes toward collars and ear markers on wildlife. *Wildlife Society Bulletin (1973-2006), 13*(3), 283-286.

Randall, C., & Rollins, R. B. (2009). Visitor perceptions of the role of tour guides in natural areas. *Journal of Sustainable Tourism*, *17*(3), 357-374.

Reading, R. P., Azua, J., Garrett, T., Kenny, D., Lee, H., Paek, W.K., Reece, N., Tsolmonjav, P., Willis, M.J. and Wingard, G. (2020). Differential movement of adult and juvenile Cinereous Vultures (*Aegypius monachus) (Accipitriformes: Accipitridae*) in Northeast Asia. *Journal of Asia-Pacific Biodiversity*, *13*(2), 156-161.

Reading, R. P., Maude, G., Hancock, P., Kenny, D., & Garbett, R. (2015). Comparing different types of patagial tags for use on vultures. *Vulture News, 67*(2), 33-42.

Rio-Maior, H., Beja, P., Nakamura, M., Santos, N., Brandão, R., Sargo, R., Dias, I., Silva, F., & Álvares, F. (2016). Rehabilitation and post-release monitoring of two wolves with severe injuries. *Journal of Wildlife Management*, *80*(4), 729-735.

Rotman, D., Preece, J., Hammock, J., Procita, K., Hansen, D., Parr, C., et al. (2012). Dynamic changes in motivation in collaborative citizen-science projects. *Proceedings of the ACM 2012 conference on computer supported cooperative work, CSCW '12* (pp. 217-226). New York, NY, ACM.

Rushworth, I. & Chittenden, H., 2004, 'Palm-nut Vulture *Gypohierax angolensis'*, in A. Monadjem, M.D. Anderson, S.E. Piper & A.F. Boshoff (eds.), *The Vultures of Southern Africa–Quo Vadis? Proceedings of a workshop on vulture research and conservation in southern Africa*, (pp. 46–50), Birds of Prey Working Group, Johannesburg.

Rust, N. A., Abrams, A., Challender, D. W., Chapron, G., Ghoddousi, A., Glikman, J. A., Gowan, C. H., Hughes, C., Rastogi, A., & Said, A. (2017). Quantity does not always mean quality: The importance of qualitative social science in conservation research. Society & natural resources, 30(10), 1304-1310.

Ryan, G. W., & Bernard, H. R. (2000). Techniques to identify themes in qualitative data. *Field Methods*, 15, 85-109.

SANParks. (2007). *Implementing Patagial Tagging on Vultures in Southern Africa.* https://www.sanparks.org/news/implementing-patagial-tagging-on-vultures-in-southern-africa

SANParks. (2023). *South African National Parks Annual Report 2022/2023*. https://www.sanparks.org/wp-content/uploads/2023/09/SANParks-Annual-Report-2022-2023.pdf

Santangeli, A., Pakanen, V.-M., Bridgeford, P., Boorman, M., Kolberg, H., & Sanz-Aguilar, A. (2020). The relative contribution of camera trap technology and citizen science for estimating survival of an endangered African vulture. *Biological Conservation*, *246*, 108593. https://doi.org/10.1016/j.biocon.2020.108593

Sarkar, D., Bortolamiol, S., Gogarten, J. F., Hartter, J., Hou, R., Kagoro, W., Omeja, P., Tumwesigye, C., & Chapman, C. A. (2022). Exploring multiple dimensions of conservation success: Long-term wildlife trends, anti-poaching efforts and revenue sharing in Kibale National Park, Uganda. *Animal Conservation*, *25*(4), 532-549.

Siemer, W. F., Brown, T. L., Martin, P. P., & Stumvoll, R. D. (1991). Tapping the potential of the wildlife rehabilitation community for public education about wildlife damage management. *Proceedings of the Eastern Wildlife Damage Management Conference* (Vol. 5, pp. 143-147).

Silvy, N. J., Lopez, R. R., & Peterson, M. J. (2012). Techniques for marking wildlife. *Wildlife Techniques Manual*, *1*, 230-257.
VulPro (n.d.). *Vulture Tracking*. https://www.vulpro.com/vulture-tracking/
Watson, D. M., & Watson, M. J. (2015). Wildlife restoration: mainstreaming translocations to keep common species common. *Biological Conservation*, *191*, 830-838.
Wilson, R. P., & McMahon, C. R. (2006). Measuring devices on wild animals: what constitutes acceptable practice? *Frontiers in Ecology and the Environment, 4(3),* 147-154.
Wilson, C., & Tisdell, C. A. (2005). What role does knowledge of wildlife play in providing support for species' conservation? *Journal of Social Sciences*, *1*, 47-51.
Wolter, K., Neser, W., & Hirschauer, M. (2018). *Protocols for mass capturing, handling, and fitting tracking devices and patagial (wing) tags on vultures.* VulPro NPC, Scheerpoort, South Africa.

3.10 Supplementary Information

Supplementary Information Questionnaire S3.1: Pilot Questionnaire

Part 1

1. Have you ever seen animals with collars/tags/harnesses in KNP?

[Participants are shown various images of marked wildlife].

2. How do you feel when you see an animal with a collar or tag?

3. Do you know any reasons why an animal might be tagged/collared etc?

Part 2 – Vultures

4. Take a look at this photograph, have you ever seen this bird? (If not, tell the participant what type of bird it is. If yes, ask them what type of bird it is).

[Participants are shown an image of a white-backed vulture]

5. What is the first thing that comes to mind when you see a vulture?

6. Can you name any vulture species that are found in South Africa?

7. Do you think vultures are important? Why do you feel this way?

8. How do you think vulture populations are doing currently? Do you think they are increasing/decreasing/staying the same? Why?

9. Do you know why vulture populations are in decline? (Inform of current threats to vultures)

10. Have you ever seen a vulture with a wing-tag like this? (Show picture)

11. If they have seen a tagged vulture then:

- Ask for more details such as the location, when did they see it, do they know what species they spotted with a tag?
- How did you feel when you saw the vulture with a wing-tag?
- What did you do when you spotted the tagged vulture? Did you report it to anyone, take a photo? Please provide details of what you did or didn't do and why.
- If you reported the sighting, who did you contact and what reaction/response/feedback did you get, if any?
- If they haven't seen a tagged vulture, then ask the participant how the photograph of the vulture with a wing-tag makes them feel and why.

12. Can you think of any reasons why vultures may be tagged with a wing-tag?

13. If yes, can you explain how you know about wing-tagging?

14. Do you think the reasons for tagging are important? (Give some information on tagging, its purpose, how the reports of sightings are used in conservation research)

15. If you see a tagged vulture in the future, will you report it? Please explain your answer.

16. Is there anything you can recommend to the researchers who study vultures using the sightings of tagged birds, that would assist in making the programme work more effectively?

Supplementary Information Questionnaire S3.2: Structured questionnaire

Questions in black were asked to all stakeholder groups; Field guides, wildlife photographers, conservation staff, locals and international tourists. Questions in red were asked to wildlife photographer, questions in green were asked to field guides.

1. Do you live in South Africa?

2. Which province do you live in?

3. Are you any of the following?

- A wildlife photographer
- A qualified field guide
- Working in a wildlife conservation-based career
- None of the above

4. Have you ever seen a wild animal with a collar/tag/GPS harness or other marking method? If so, please give details of what species you have seen and what marking method they had. *Here are some examples of marked animals [Participants are shown various images of marked wildlife].*

5. How do you feel when you see a wild animal with a collar/tag/GPS harness or other marking method?

5a. Would you rather photograph a wild animal with or without a collar/tag/GPS harness or other marking method? Please explain your answer.

5b. How would you feel about showing a marked animal to guests? Please explain your answer.

5c. Generally, how do guests react to these sightings (if applicable)?

- Positive
- Negative
- Neutral
- Not applicable

5d. What kind of questions have guests asked at a sighting of a marked animal?

5e. What information would you give to guests if they asked for reasons why a wild animal might have a collar/tag/GPS harness or other marking method?

6. Do you know any reasons why a wild animal might have a collar/tag/GPS harness or other marking method? Please list.

7. Have you ever seen this bird? [Link to bird image]

8. Can you name what type of bird it is?

9. Can you name any vulture species found in South Africa? Please list.

10. Do you think vultures are important? Why do you feel this way?

10a. What information would you give your guests at a vulture sighting?

11. How do you think vulture populations are doing currently in South Africa?

- Increasing
- Decreasing
- Staying the same
- Other

All five of the vulture species that are found in the Kruger National Park are currently at risk. The hooded vulture, white-headed vulture and white-backed vulture are critically endangered, the lappet-faced vulture is endangered, and the Cape vulture is vulnerable.

12. Do you know any reasons why vulture populations are currently in decline? Please list.

13. Have you ever seen a vulture with a wing-tag like this? [Link to vulture image]

14. When and where did you see the tagged vulture?

14a. Did you photograph the tagged vulture?

14b. How did the guests react to the sighting of the tagged vulture, if applicable?

15. Did you report the sighting of the tagged vulture?

16. Who did you report the sighting of the tagged vulture to?

17. What information did you give when you reported the sighting?

18. Did you receive any feedback?

19. Do you know that sightings of tagged vultures should be reported?

Sightings of tagged vultures can be reported to the Endangered Wildlife Trust at resightings@ewt.org.za

Please include:

- *The wing-tag number.*
- *The location of the vulture (coordinates or a pin-drop if possible).*
- *The date of the sighting.*
- *A photograph, if you are able to take one.*

20. How do you feel when you see a wing-tagged vulture? [Link to wing-tagged vulture image]

- Very positive
- Positive

- Neutral
- Negative
- Very negative

20a.What information would you give guests at a sighting of a tagged vulture?

20b. Would you rather photograph a vulture with or without a wing-tag? Please explain why/why not.

21. Can you think of any reasons why vultures are tagged with wing-tags? Please list.

Wing-tagging helps with vulture population studies. Through reported sightings of tagged vultures, researchers are able to study movements patterns, preferred habitats and survival rates. Wing-tagging vultures also helps to identify threats to vultures as when fatalities are reported, scientists can determine a cause of death. This data helps to create effective vulture conservation strategies.

22. Do you think the reasons for tagging are important? Please give a reason for your answer.

23. Is there anything you can recommend to researchers to encourage people to report sightings, and make reporting sightings easier?

24. If you see a tagged vulture in the future, will you report it?

24a. Will you encourage guests to report sightings of tagged vultures?

CHAPTER 4

Assessing conservation strategies for vultures: Rehabilitation, release, and patagial tagging

Emma B. Laurieston [1], Lindy J. Thompson[1,2,3], John P. Davies[2], Gareth J. Tate[2, 4] and Colleen T. Downs[*1]

[1]*Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg, 3209, South Africa*

[2]*Birds of Prey Programme, Endangered Wildlife Trust, Midrand, South Africa*

[3]*Southern African Wildlife College, Kempiana Nature Reserve, Hoedspruit, South Africa*

[4]*FitzPatrick Institute of African Ornithology, University of Cape Town, Cape Town, South Africa*

Formatted as a manuscript for submission to an international peer-reviewed journal.

* Corresponding author: Colleen T. Downs
Email: downs@ukzn.ac.za; ORCID: http://orcid.org/0000-0001-8334-1510

Other emails and ORCIDs of others:

EB Laurieston Email: emmalaurieston4@gmail.com; ORCID: https://orcid.org/0009-0009-4157-2359
LJ Thompson Email: LindyJane.Thompson@gmail.com; ORCID: https://orcid.org/0000-0001-9847-2003

JP Davies Email: JohnD@ewt.org.za ORCID: https://orcid.org/0000-0003-0252-7650

GJ Tate Email: GarethT@ewt.org.za ORCID: https://orcid.org/0000-0002-1816-317X

Running header: Efficacy vulture rehabilitation and release

4.1 Abstract

With vulture populations in South Africa facing significant conservation challenges, the role of rehabilitation centres has become pivotal in treating injured and poisoned birds, and releasing them back into the wild, aiming to restore vulture populations. We aimed to evaluate the effectiveness of rehabilitation initiatives by comparing the behaviour and survival outcomes of rehabilitated vultures with wild vultures using tagged individuals. We analysed dispersal distances and survival rates of wild and rehabilitated vultures using data from a vulture wing-tag resighting database. The data were collected from 2015 – 2023 in Limpopo and Mpumalanga provinces and included White-backed Vultures (*Gyps africanus*), Cape Vultures (*Gyps coprotheres*), Hooded Vultures (*Necrosyrtes monachus*), Lappet-faced Vultures (*Torgos tracheliotos*), and White-headed Vultures (*Trigonoceps occipitalis*). The findings indicated that although rehabilitated vultures exhibited slightly greater dispersal distances than wild vultures, the practical significance of this variance was minimal. Notably, the two groups had no significant differences in survival probabilities, suggesting that rehabilitation processes effectively prepare vultures for successful reintroduction. However, challenges such as initial post-release mortality and potential long-term impacts of the rehabilitation process on vulture fitness were identified. These insights underscore the necessity for ongoing research and proactive conservation strategies to safeguard African vulture populations against anthropogenic threats.

Keywords: Vulture, Conservation, Rehabilitation, Wing-tag, Survival

4.2 Introduction

Vulture populations across Africa are undergoing rapid declines, with six vulture species now classed as endangered or critically endangered (IUCN, 2022). As obligate scavengers, vultures provide essential ecosystem services by consuming carrion and ridding the land of carcasses that are potentially infected with harmful pathogens (Markandya et al., 2008a; Margalida & Colomer, 2012; Ogada et al., 2012a; 2012b; Buechley & Şekercioğlu, 2016; Ives et al., 2022). The loss of vultures in Africa would likely have devastating impacts, both on the environment and human health (Markandya et al., 2008b), as seen during the 'Asian Vulture Crisis' that occurred in the late 1990s. During that time, the populations of three species of *Gyps* vultures plummeted across Asia, causing the number of vultures to decrease by over 96% in only 10 years (Ogada et al., 2016a). This was the result of poisoning with Diclofenac, a non-steroidal anti-inflammatory drug commonly used to treat livestock, which the vultures consumed and were subsequently poisoned by (Green et al., 2004). With vultures absent from the environment, dead animals were not consumed, and this created a plentiful food source for feral dogs, causing an increase in their numbers. Rabies transmission was reported to increase as a result of this, estimated to have caused an additional ~$34 billion in healthcare costs in India between 1993 and 2006 (Ogada et al., 2016a; 2016b). Alarmingly, the rate of the current population decrease of African vultures is comparable to the rate of decline seen during the Asian Vulture Crisis (Ogada et al., 2016a).

These devastating losses mainly result from anthropogenic activities (Ogada et al., 2016a; Ottinger et al., 2021). Vultures are poisoned for various reasons, including to obtain their body parts for sale to traditional healers for use in African traditional medicine, where their body parts are consumed, snorted, drank or applied to wounds to provide protection, good fortune, and clairvoyant abilities (Mashele et al., 2021). Ivory poachers poison vultures to avoid detection by the authorities, a practice known as 'sentinel poisoning' (Santangeli et al., 2017;

Gore et al., 2020). Poisoning the carcass of a poached elephant (*Loxodonta africana*) or other large carcass may result in the deaths of dozens or hundreds of vultures, preventing them from circling over the crime scene and alerting rangers (Ogada et al., 2016b; Daboné et al., 2023b). Furthermore, habitat loss driven by urbanisation and the expansion of agriculture has significantly impacted vulture populations, as have collisions with motor vehicles, fences and powerlines, contributing substantially to vulture mortality (Naidoo et al., 2011; Ogada et al., 2016a; Craig et al., 2019; Yee et al., 2021; Daboné et al., 2023b).

Presently, there are teams of conservationists working to conserve vulture populations in South Africa through the rehabilitation and release of injured and poisoned birds (Naidoo et al., 2011; Monadjem et al., 2014; Mashele et al., 2022). With incidences of mass-poisoning still a common occurrence (Ogada et al., 2012a; Murn & Botha, 2018) and as vulture numbers continue to plummet (IUCN, 2022), more research is necessary to evaluate the efficacy of vulture rehabilitation and release. While the vulture rehabilitation process has proved successful (Naidoo et al., 2011), the performance of these birds post-release requires further study. Jobson et al. (2021) examined captive-bred and rehabilitated Cape Vultures' (*Gyps coprotheres*) home ranges and habitat selection compared with wild conspecifics. They found that captive-bred birds stayed closer to their release site than rehabilitated birds who followed their species' normal home range and dispersed as widely as wild birds (Jobson et al. 2021). Comparative studies like this can also reveal important ecological differences between rehabilitated and wild vultures. "Rehabilitated vulture" refers to any vulture that was admitted to a rehabilitation centre for treatment after an injury or poisoning, and released once declared healthy. Conversely, "wild-caught vulture" refers to any vulture that was trapped in the wild, tagged and released immediately. Calculating survival probabilities and dispersal distance differences between these two groups is needed to understand population dynamics when managing and conserving vultures (Lagrange et al., 2014).

In the Lowveld region of South Africa, the Endangered Wildlife Trust has been applying patagial (wing) tags to rehabilitated and wild vultures. The patagial tags display identification codes that are unique to each bird. Sightings of the tagged vultures are then reported by researchers, field guides, tourists and members of the public, allowing the vulture individuals to be tracked and monitored over time.

This study aimed to evaluate the effectiveness of rehabilitation initiatives and post-release monitoring techniques by comparing the behaviour and survival outcomes of rehabilitated vultures with wild vultures. Here, we compared the dispersal distance and survival rate of rehabilitated and wild vultures, using the Endangered Wildlife Trust's vulture resighting database in Mpumalanga and Limpopo provinces, South Africa. We predicted that rehabilitated vultures would exhibit similar dispersal distances and survival rates to wild vultures. This would suggest that rehabilitation efforts are effective in restoring these birds to a state where they can thrive in the wild.

4.3 Methods

This research was also conducted under a Limpopo Economic Development, Environment & Tourism permit (ZA/LP/116483). Permission was granted by the Endangered Wildlife Trust to access and analyse the EWT Vulture Resighting Database.

4.3.1 Study areas and the Endangered Wildlife Trust database

The Endangered Wildlife Trust vulture resighting database began with reports of leg ringed vultures in the 1970's. The database includes vultures tagged by various South African vulture conservation organisations, including Ezemvelo KZN Wildlife, VulPro and Wildlife ACT. The first resighting record of a vulture marked with a patagial tag was in 2004. Since then, the organisations employed wing-tags as a primary method for monitoring vultures. For this case

study, we analysed records of vultures from the A series; namely vultures tagged by Endangered Wildlife Trust, specifically in the Limpopo and Mpumalanga provinces, which include the Kruger National Park and the Kruger-to-Canyon Biosphere Region. This study area, situated within the Lowveld region, predominantly consists of savannah, woodland, riverine forests, and the Drakensberg Mountain range (Department of Forestry, Fisheries and the Environment, 2024). We opted to analyse data from the A series to ensure consistency in our study sample. All rehabilitated vultures included in this series were treated at Moholoholo Wildlife Rehabilitation Centre (30.90°E, 24.52°S), which is located in Limpopo Province, close to the towns of Kampersrus and Hoedspruit, South Africa. Vultures in this area are admitted to Moholoholo Wildlife Rehabilitation Centre, and are often treated for poisonings, as well as injuries resulting from collisions with powerlines and persecution by the public (Mashele et al., 2022). However, the specific cause of admission to a rehabilitated centre for each vulture in the present study was unknown.

By focusing on this specific subset of patagial tagged vultures, we aimed to minimise potential variability in the results caused by differences in rehabilitation protocols across multiple centres. We focused our dataset on the 213 vultures tagged after 2015, in the Lowveld, with A-series tags. We chose these birds to prioritise recent data, enhancing the study's relevance to present-day conservation efforts. The dataset included Cape Vultures, Hooded Vultures (*Necrosyrtes monachus*), Lappet-faced Vultures (*Torgos tracheliotos*), White-backed Vultures (*Gyps africanus*) and White-headed Vultures (*Trigonoceps occipitalis*). Each vulture was assigned to an age category based on its age at the time of tagging: nestling (tagged while still in the nest), juvenile (not yet reached adult plumage), and adult (based on adult plumage or other factors such as the eyes turning yellow in Cape Vultures (Mundy, 1982)).

4.3.2 Data analyses

We performed data cleaning procedures using R statistical software (version 4.2.1, R Core Team, 2022). We calculated various descriptive statistics from the entire database, including the number of vultures tagged over the years, the total number of each species tagged, and the mean and longest duration a bird was tagged and resighted for. For the case study, we refined the dataset only to include records of A series vultures tagged after 2015. We removed duplicate entries and filtered out records with missing or inaccurate information to ensure data accuracy. Following data cleaning, we used descriptive statistics to summarise key characteristics of the dataset, such as the total number of each species and the number of vultures that were not sighted again after being tagged.

'Dispersal distance (km)' of each A series tagged vulture was calculated by taking the furthest straight-line distance each individual vulture travelled from its initial tagging location for rehabilitated vultures and wild vultures. Those not sighted again after initial tagging were removed from the analysis. This approach ensured that our assessment reflected the behaviour of vultures that survived beyond the tagging period. We performed a Mann-Whitney U test to evaluate the effect of vulture status (rehabilitated or wild-caught) on dispersal distance. Furthermore, we performed a Kruskal-Wallis test to determine the effect of vulture species on dispersal distance. Although the Kruskal-Wallis test does not require equal variances, Levene's test was conducted to confirm homogeneity of variances among species. The test indicated similar variances across groups ($p = 0.193$), reinforcing the validity of the Kruskal-Wallis test results and ensuring that any observed differences were likely due to medians rather than variance discrepancies. Due to missing age data in some reports, a subset of the data containing vultures with known ages was used in an additional Kruskal-Wallis test to explore potential age-related differences in dispersal distance. We provide the median dispersal distances from

the initial tagging site for each group to illustrate the mean distance travelled, avoiding the influence of extreme values.

To determine the survival status of vultures, we examined the time intervals between consecutive sightings for each vulture in our dataset. We found that the 95th percentile threshold exceeded 655 days. Consequently, any vulture not sighted within this timeframe, 655 days or more, was presumed deceased. Those seen within 655 days were said to be surviving. We also calculated the total number of days since each bird was tagged. Subsequently, the survival rate was estimated using Kaplan-Meier analysis, followed by a Cox proportional hazards test, which compared differences in survival rate based on the survival status of species. We chose to use Kaplan-Meier analysis because it allows for the incorporation of censored data (i.e. observations where the event of interest (death) has not yet occurred by the end of the study or the survival outcome of the individual is unknown) and accounts for observed deaths within the vulture population, providing a robust method to determine survival rates despite mortality events.

4.4 Results

4.4.1 Patagial tagging as a vulture monitoring tool

The analysis of the Endangered Wildlife Trust Vulture Resighting Database revealed trends in vulture tagging activities in South Africa. The earliest recorded entry in this database dates back to 1974, marking the first documented instance of tagging efforts using leg rings in this particular database (Figure 4.1). This method gained popularity in the country during the 1980s but experienced a decline in the late 1980s and early 1990s.

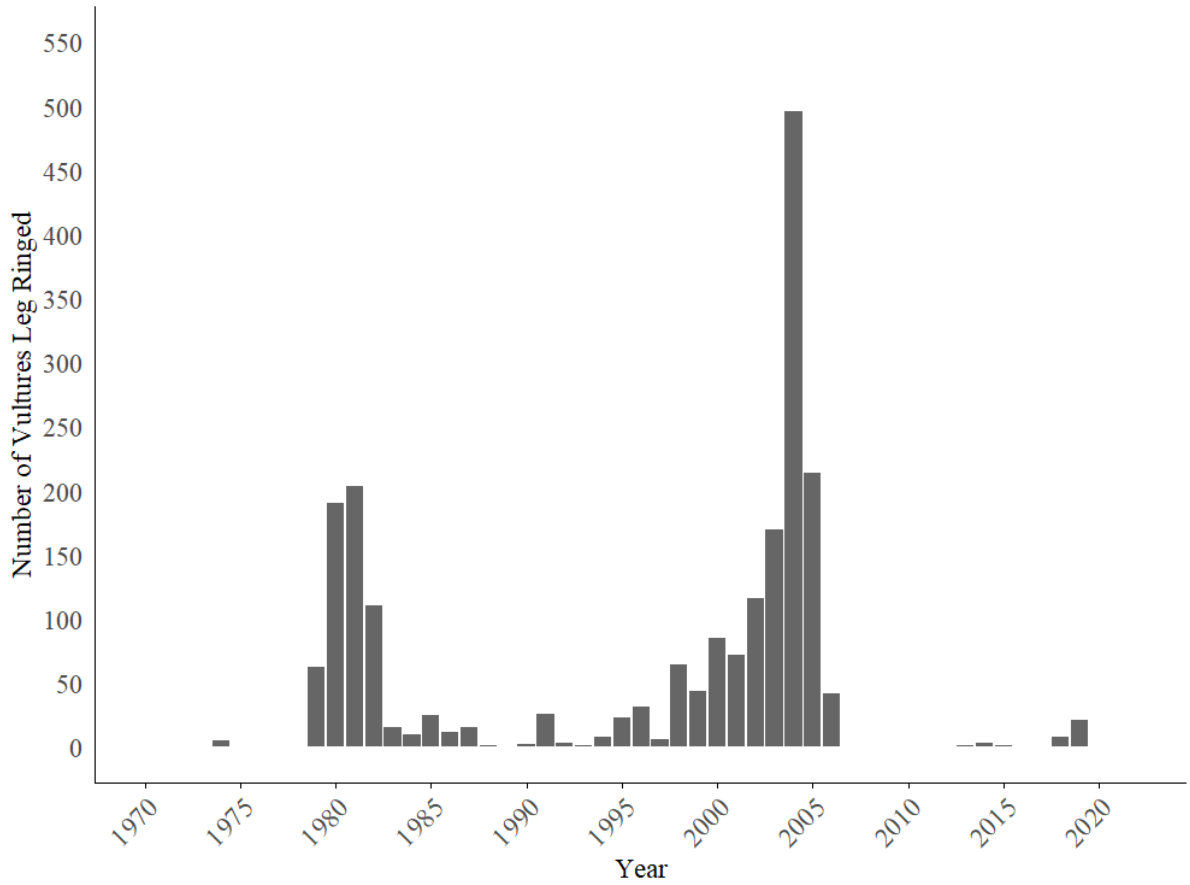


Figure 4.1: Number of vultures tagged with leg-rings alone over time (years).

A resurgence in leg ringing occurred in the early 2000s, with a notable spike in activity in 2005. However, after 2005, the use of leg rings alone decreased significantly. This period also marks the inception of patagial tagging, with the first recorded instance appearing in 2005. From this point onward, vultures were generally tagged with both leg rings and patagial tags. The combined tagging method peaked in popularity in the late 2000s, with nearly 800 vultures tagged in 2007 (Figure 4.2). Throughout the 2010s, the number of tagged birds remained relatively high, with annual totals ranging between 400 and 600 until 2018. Following 2018, there was a sharp decline in tagging activities, with fewer than 100 birds tagged in 2020 and 2022

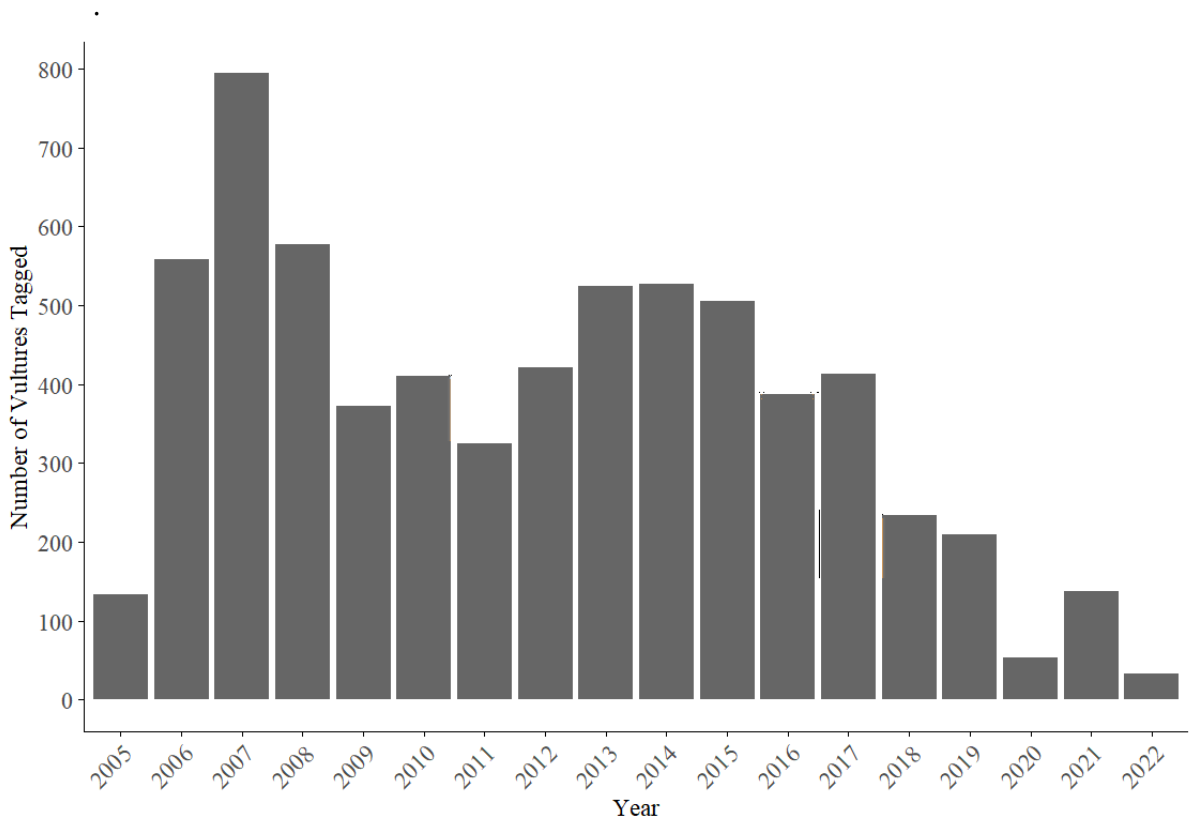


Figure 4.2: Number of vultures tagged with both wing-tags and leg rings over time (years).

Since the beginning of this database, a total of 2,086 vultures have been leg-ringed in South Africa. Additionally, 6,619 vultures have been tagged using a combination of both patagial tags and leg rings. Vultures were tagged in seven countries, including South Africa, Namibia, Bostwana, Mozambique, Eswatini, Zimbabwe and Zambia (Figure 4.3). The database includes a total of 33,154 patagial tag resighting reports.

Various vulture species have been tagged in South Africa. Specifically, the database includes 1,245 Cape Vultures, 25 Hooded Vultures, 1,251 Lappet-faced Vultures, 4,065 White-backed Vultures, and 33 White-headed Vultures. The longest reported duration for a tagged vulture extends from 17 February 2004 to 3 November 2016, totalling 12 years, 8 months, 3 weeks, and 2 days. We found that, on average (mean), vultures were observed and reported for a continuous period of 233 days before no further reports were made. Additionally, it was observed that 75% (n = 4967) of the tagged vultures were not reported at all after being tagged.

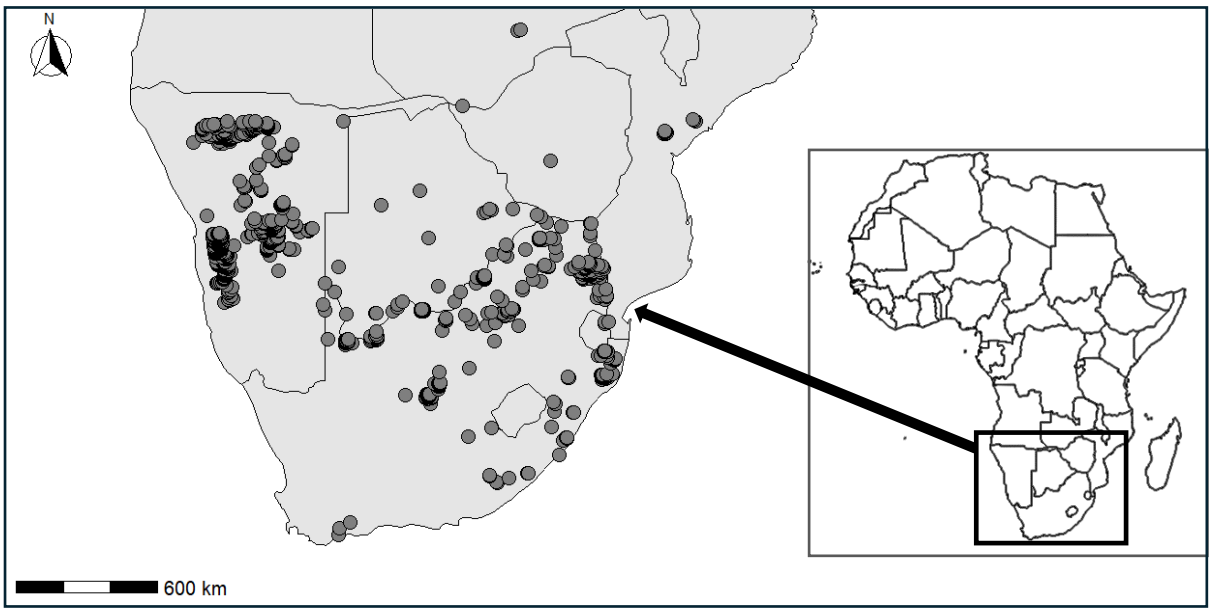


Figure 4.3: Map of vulture tagging locations included in the Endangered Wildlife Trust Vulture Resighting Database.

4.4.2 Case study: The Endangered Wildlife Trust vultures tagged with A series patagial tags

4.4.2.1 Population characteristics

Our dataset included information on 213 vultures, comprising 81 rehabilitated vultures and 132 wild-caught vultures, which together gathered 780 sighting reports. Among the rehabilitated vultures, 11 were Cape Vultures, two were Hooded Vultures, two were Lappet-faced Vultures, 65 were White-backed Vultures, and one was a White-headed Vulture. Conversely, the wild vultures consisted of five Cape Vultures, seven Hooded Vultures, four Lappet-faced Vultures, 114 White-backed Vultures, and two White-headed Vultures (Table 4.1).

Table 4.1: The total number of each vulture species tagged per rehabilitated and wild-caught vultures in the present study.

Species	**Latin name**	**Wild-caught**	**Rehabilitated**
Cape Vulture	*Gyps coprotheres*	5	11
Hooded Vulture	*Necrosyrtes monachus*	7	2
Lappet-faced Vulture	*Torgos tracheliotos*	4	2
White-backed Vulture	*Gyps africanus*	114	65
White-headed Vulture	*Trigonoceps occipitalis*	2	1
Total		**132**	**81**

4.4.2.2 Dispersal distance of rehabilitated and wild vultures

Tagged rehabilitated vultures were resighted in South Africa and Mozambique, while wild-caught vultures were resighted in South Africa, Botswana, and Zimbabwe (Figure 4.4). Both rehabilitated vultures (44/81, 54.3%) and wild vultures (39/132, 29.5%) were not reported again after tagging, with the proportion being significantly higher in rehabilitated vultures ($\chi^2 = 12.956$, $p < 0.001$). These birds were removed from the dispersal distance analysis to ensure an accurate representation of the behaviour of surviving vultures.

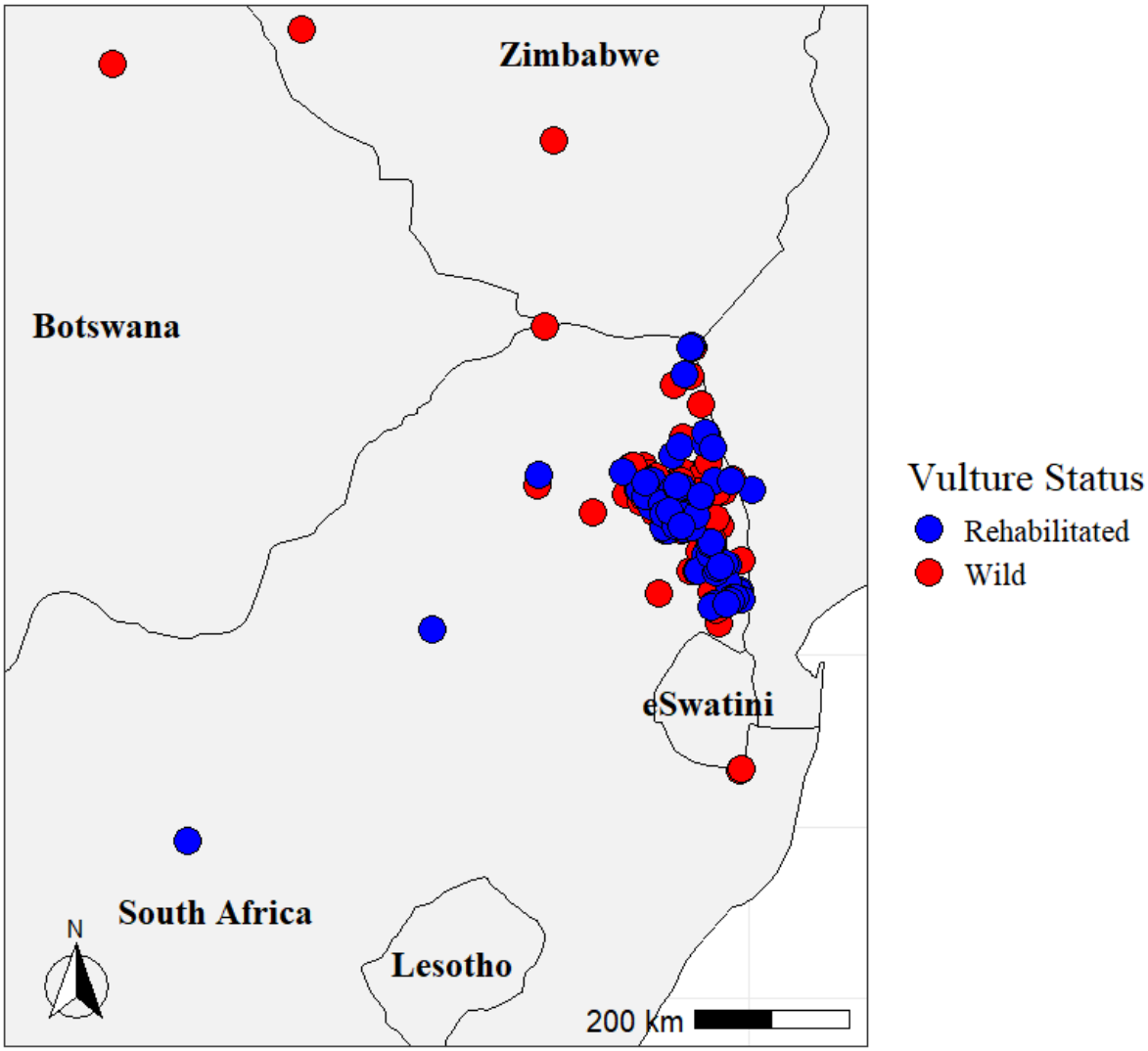


Figure 4.4: A map of sighting reports of wild-caught (red) and rehabilitated (blue) vultures belonging to the A series, tagged by the Endangered Wildlife Trust.

We performed a Mann-Whitney U test to investigate the difference in short-term dispersal distance between rehabilitated vultures (n = 35, median = 91.12 km, interquartile range = 91.23 km) and wild vultures (n = 92, median = 41.19 km, interquartile range = 45.04 km). Prior to this, we performed a Shapiro-Wilk normality test, which revealed the data as non-normally distributed, justifying the use of the Mann-Whitney U test. The analysis showed a significant difference (W = 2094, p = 0.009) between rehabilitated and wild vultures, suggesting that rehabilitated vultures dispersed further than wild vultures. However, the effect

size, measured by the Cohen's d correlation, was estimated to be 0.199, suggesting a negligible difference in dispersal distance between rehabilitated and wild vultures. The 95% confidence interval for Cohen's d ranged from -0.195 to 0.593, indicating some uncertainty in the estimate. While there was a statistical difference in dispersal distance between rehabilitated and wild vultures, the practical significance appeared to be minimal.

4.4.2.3 Dispersal distance of vulture species

We found a significant difference in short-term dispersal distance between vulture species (Kruskal-Wallis rank sum test, $\chi^2 = 16.0412$, df = 4, p = 0.003). Our post-hoc Bonferroni-corrected pairwise comparisons confirmed significant differences in dispersal distances among species. Lappet-faced Vultures exhibited a median dispersal distance of 268.45 km, significantly greater (p = 0.011) than Cape Vultures at 16.70 km. Additionally, Lappet-faced Vultures showed a significantly greater dispersal distance (p = 0.0101) than White-backed Vultures, with a median distance of 42.65 km. The effect size estimates for Lappet-faced Vultures compared with Cape Vultures (Cohen's d = 1.28, 95% CI [−0.46, 3.02]) and White-backed Vultures (Cohen's d = 2.17, 95% CI [1.12, 3.22]) were both large. However, it is important to note the small sample sizes of Lappet-faced Vultures (n = 4) and Cape Vultures (n = 5), as well as the wide confidence intervals, indicated uncertainty in the observed differences in dispersal distances among vulture species.

4.4.2.4 Dispersal distance of nestling, juvenile and adult vultures

We found a significant difference in short-term dispersal distance among the three age categories of vultures (Kruskal-Wallis rank sum test, $\chi^2 = 10.917$, df = 2, p = 0.00426). Our post-hoc pairwise comparisons with Bonferroni correction illustrated that juvenile vultures exhibited a significantly different dispersal distance than adults (p = 0.00062), with a large

effect size (Cohen's d = -0.8128, 95% CI [-1.31, -0.32]). Juvenile vultures had a median dispersal distance of 68.04 km, which was higher than the median dispersal distance of adult vultures at 35.31 km. Conversely, no significant difference in dispersal distance was observed between nestlings and adults (p = 1.000). Similarly, there was no significant difference between nestlings and juveniles (p = 0.300). The small number of nestling vultures (n = 3) in our sample suggests that we should be cautious when interpreting the results for this age group.

4.4.2.5 Survival rate

We conducted a survival analysis to assess the effect of rehabilitation on survival amongst vulture populations. A Kaplan-Meier survival curve was plotted for rehabilitated and wild vultures (Figure 4.5). No significant difference in survival probability was observed between the two groups. The survival probability of wild vultures began at approximately 0.72, indicating that some individuals did not survive long after tagging. It gradually decreased to approximately 0.4 at 1250 days. After that, the survival probability remained relatively stable, with some birds surviving beyond the study period. In comparison, the survival of rehabilitated vultures began at 0.65, also indicating that some birds did not survive long after tagging. The survival probability also then decreased (however more steeply than for wild vultures) within the first ± 600 days. The survival probability became more stable and similar to that of wild vultures after 1000 days, at approximately 0.4, until 1500 days. Here, the survival probability of rehabilitated vultures dropped to 0.0. This drop to zero for rehabilitated vultures may indicate a shorter survival duration, however, is possibly due to cases where individuals are still alive but have not been observed beyond a certain point in the study period (also known as censored data). Therefore, the drop to zero in the survival curve does not necessarily indicate that all rehabilitated vultures have died, but it is possible that there was no further resighting data for them beyond that point.

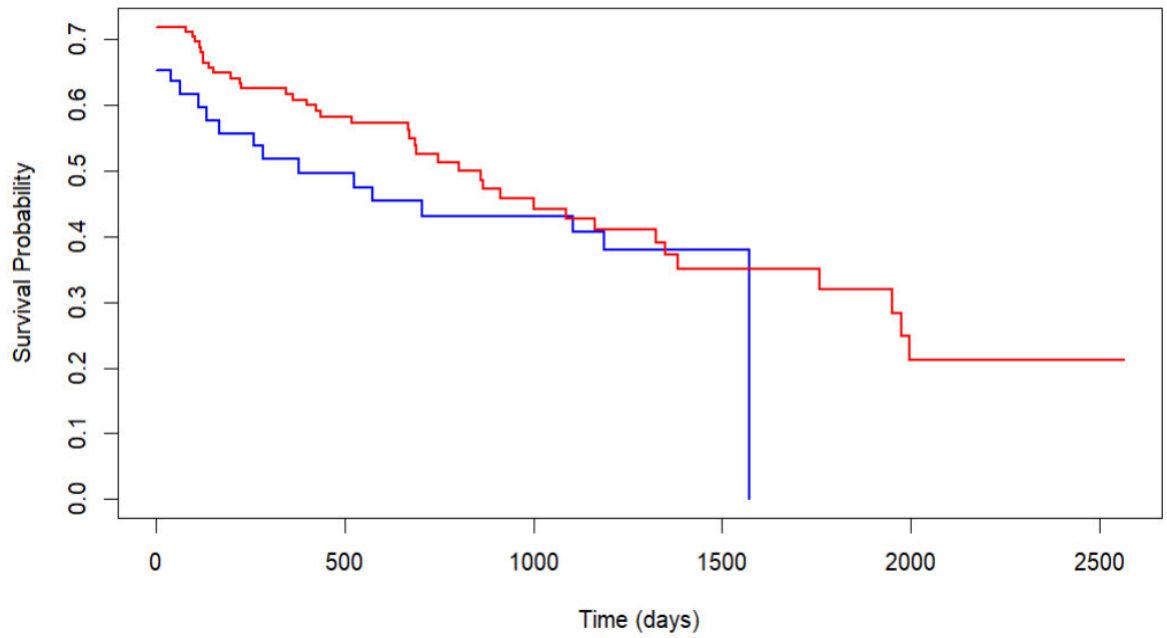


Figure 4.5: Kaplan-Meier Survival Curve for patagial tagged vultures in the Lowveld region of South Africa. This plot displays the survival probability over time for rehabilitated vultures (in blue) and wild-caught vultures (in red).

A log-rank test confirmed that there was no significant difference in survival rates between wild and rehabilitated vultures ($\chi^2 = 1$, df = 1, p = 0.3). We used a Cox proportional hazards model to further investigate the factors influencing survival. Here, we examined the effect of vulture status (rehabilitated or wild) and vulture species on survival. The results showed no significant effect of vulture status or species on survival outcomes, with both groups showing similar hazard ratios. While vulture species had some influence on survival outcomes, none of the coefficients reached statistical significance. It is important to note that the small sample sizes of some species may have influenced these results, potentially masking the actual effects of species on survival.

The Cox proportional hazards model demonstrated moderate concordance (c = 0.561), indicating reasonable predictive accuracy. Although the likelihood ratio, Wald, and score tests

suggested some statistical significance, the p-values did not reach the conventional threshold for significance ($p > 0.05$), suggesting limited evidence for the model's predictive power.

4.5 Discussion

4.5.1 Patagial tagging as a vulture monitoring tool

The Endangered Wildlife Trust Vulture Resighting Database contains a wealth of valuable information that provides insight into the historical trends and patterns of vulture tagging activities in South Africa. The fluctuating popularity of tagging methods over time indicates shifts in research priorities, technological advancements, or conservation strategies. The transition from solely using leg rings to incorporating patagial tags reflects a possible adaptation to enhance the effectiveness of tracking efforts. Patagial tagging, which became the more popular marking technique in South Africa in 2005, provided additional identification and tracking capabilities. This trend of moving from leg ringing alone to a combination of leg ringing and patagial tagging for vulture research appears to have occurred on a broader scale around the same time frame. Research in Mongolia on Cinereous Vultures (*Aegypius monachus)* with patagial tags began in 2002 (Batbayar et al., 2008). Similarly, in the United States, the study of Turkey Vultures (*Cathartes aura*) underwent a transition from using leg rings to patagial tags. Leg rings were commonly employed for research purposes until the 1970s, after which their popularity decreased. This decline coincided with the rising popularity of patagial tagging, which gained traction after 1994 (Houston & Bloom, 2005).

In South Africa, the peak in combined tagging efforts during the mid-2000s to the mid-2010s highlights a period of heightened interest and investment in vulture conservation initiatives. The substantial number of vultures tagged annually during this time underscores concerted efforts to gather data on vulture movements, behaviour, and population dynamics.

The significant decrease in tagging activities observed after 2018 prompts an exploration of potential contributing factors. Shifts in funding priorities, alterations in research focus, or logistical hurdles linked to tagging operations may all have played a role. However, it's also worth considering the impact of external factors, such as the COVID-19 pandemic, which could have led to disruptions in research projects and conservation efforts (Corlett et al., 2020; Primack et al., 2021). Understanding the drivers behind this decline is crucial for informing future conservation strategies and ensuring the continuity of vulture monitoring efforts.

Furthermore, the geographic scope of tagging activities spanning seven countries underscores the collaborative nature of vulture research and conservation efforts in the region. The inclusion of data from multiple countries provides a broader context for understanding vulture ecology and informs transboundary conservation initiatives aimed at safeguarding vulture populations across their range.

The patagial tags have proven useful in collecting long-term data on vulture movements over extended periods of time. However, it is important to note that a considerable number of tagged birds were not resighted after being tagged. This raises questions about the reliability and durability of tagging methods and demonstrates the need for further research to determine whether the absence of resightings is because of tags breaking or falling off or if it is indicative of mortality among tagged individuals. This is particularly important given the findings from Curk et al. (2021) suggesting a potential negative impact of tagging on vulture fitness. Investigating the factors influencing resighting rates and addressing any potential adverse effects of tagging on vulture health are essential for ensuring the effectiveness and ethical implementation of conservation interventions.

4.5.2 Case study: The Endangered Wildlife Trust vultures tagged with A series patagial tags

Our analysis of data from a vulture patagial tag resighting database in southern Africa revealed no significant difference in survival probabilities between wild-caught and rehabilitated vultures. We compared the short-term dispersal distance and survival rate of rehabilitated and wild vultures, while also investigating the effect of other factors such as species and age. These findings suggest that vulture status, whether rehabilitated or wild, may not be a significant predictor of survival outcomes in the studied population. However, further research is warranted to explore additional factors that may influence vulture survival, with implications for conservation efforts and population management strategies.

4.5.2.1 Dispersal distance of wild vs rehabilitated vultures

Our study showed that rehabilitated vultures appeared to disperse further from their tagging locations than wild vultures. This could be because the wild vultures were caught within their home range, tagged and released in the same area, whereas rehabilitated vultures often were found injured or poisoned far from the rehabilitation centre. All rehabilitated vultures in this dataset were tagged and released at Mohololoholo Wildlife Rehabilitation Centre's vulture restaurant (a supplementary feeding site for vultures). This means they may have travelled back to their nesting site, possibly hundreds of kilometres away from the tagging location, accounting for the difference in dispersal distance between wild and rehabilitated vultures. However, despite the observed difference, the effect size was small, with uncertainty in the estimate. Understanding the dispersal behaviour of rehabilitated vultures compared with wild vultures provides insights into their post-release adaptation and behaviour (Jobson et al., 2021). This knowledge can inform rehabilitation protocols to better prepare vultures for successful reintroduction (Fozzi et al., 2023). Future research into the dispersal distance of rehabilitated

vs wild vultures should be conducted with GPS tracking data over an extended period of time to provide more accurate data.

4.5.2.2 Dispersal distance of vulture species

The results of our study demonstrate that Lappet-faced Vultures had a significantly greater dispersal distance than White-backed Vultures and Cape Vultures. These results differ from that of Spiegel et al. (2013), who reported that Lappet-faced Vultures tend to be territorial (Pennycuick, 1972) and stay in their fixed and relatively small foraging ranges, compared with White-backed Vultures and Cape Vultures who are known to travel great distances in search for carrion and feed in large numbers (Bamford et al., 2007). Our results could be attributed to the larger body size and wingspan of Lappet-faced Vultures, enabling them to cover greater distances quicker and efficiently exploit weaker thermals (Pennycuick, 1972; Spiegel et al., 2013). Additionally, they may have to travel greater distances to find food sources that are not already occupied by other territorial Lappet-faced Vulture pairs (Pennycuick, 1972; Shimelis et al., 2005; Spiegel et al., 2013). However, it is important to note that our study had a small sample size of only four Lappet-faced Vultures, which may have been influenced by extreme values and may not be representative of the species as a whole. Variation in dispersal distance among vulture species highlights the importance of considering species-specific behaviours and ecological requirements in conservation strategies. By identifying species with larger habitat ranges, conservation efforts can focus on habitat protection to support the movement and foraging needs of these species. Therefore, further research with larger sample sizes is needed to provide a more comprehensive understanding of the dispersal behaviour of rehabilitated vultures of various African species.

4.5.2.3 Dispersal distance of nestling, juvenile and adult vultures

Juvenile vultures exhibited a tendency to travel greater distances than adult vultures, consistent with findings reported by Bamford et al. (2007), who observed the same behaviour in juvenile Cape Vultures. Mundy (1992) suggested that juvenile vultures disperse to regions with fewer adult vulture populations, possibly to avoid competition at carcasses. The juveniles in this study may also disperse to regions where they can feed without the constraints imposed by age hierarchies at carcasses. This pattern of juveniles travelling further than adults was also observed in Cape Vultures (Phipps et al., 2013), and in Bearded Vultures (*Gypaetus barbatus*) in southern Africa (Krüger et al., 2014) and in Europe (Gil et al., 2010; Margalida et al., 2013). Another plausible explanation for the larger dispersal distance in juveniles compared with adults could be that juveniles travel further because of their exploratory nature. As they grow from fledglings to juveniles, then to subadults, and into adulthood, they travel through and discover their home ranges, venturing further from their natal area (Gil et al., 2010; Margalida et al., 2013; Krüger, 2014). Additionally, differences in dispersal distances between juveniles and adults may stem from differences in their life stages and associated behaviours. Adults remain in the same area for nesting and breeding purposes, and to provide post-fledgling parental care to their offspring (Krüger & Amar, 2017; Martens et al., 2018; Daboné et al., 2023a), while juveniles are free to roam more widely as they are not as tied to nest sites. Consequently, the behaviour of adults likely contributes to their lower dispersal distances compared with the exploratory nature of juvenile vultures. Understanding the difference in dispersal distances between age groups, and the factors driving these differences can inform targeted conservation efforts to mitigate threats during vulnerable life stages. Additionally, assessing the post-release behaviour of juvenile vultures is crucial to evaluate the efficacy of rehabilitation programmes and to identify if there are any issues that need addressing to best integrate juveniles into wild populations.

4.5.2.4 Survival rate

Our survival analysis revealed no significant difference in survival probabilities between wild and rehabilitated vultures. This is an important finding as it shows that the Mohololoholo Wildlife Rehabilitation Centre effectively treats injured and poisoned vultures. Rehabilitated vultures did, however, experience a steeper decline in survival probability within the first 750 days post-release than wild vultures, suggesting a potentially higher mortality rate. This could be attributed to long-term health effects of vultures being admitted to the rehabilitation centre in a weakened state, having been injured or poisoned. Consequently, their compromised physical condition may hinder their ability to survive or compete for resources once released (Naidoo et al., 2011; Cope et al., 2022). The effects of the rehabilitation process on post-release fitness may also play a role (Cope et al., 2022). During their time in captivity, these vultures are placed in a controlled environment where humans provide food. This artificial provisioning could potentially lead to a dependency on human-provided food, and a higher body weight, resulting in impaired scavenging skills once released into the wild (Champagnon et al., 2012). Also, whilst receiving veterinary treatment, they are kept in cages and have limited flight and exercise opportunities, resulting in potential muscle weakness over time (Hawkins, 2010; Kaplan, 2021). Mohololoholo tries to complete the rehabilitation process within 14-21 days, however, this time at the centre still possibly hinders their foraging and flight ability once released into the wild. Additionally, the stress incurred during veterinary treatment and confinement in captivity may also have detrimental effects on their overall fitness post-release (Wolter et al., 2019; Forbes, 2020; Glucs et al., 2020). Wild vultures, on the other hand, do not face these same challenges as they are trapped, tagged and released in the same morning, in the same area. Conversely, rehabilitated vultures are often found and brought to the rehabilitation centre from hundreds of kilometres away (Mashele et al., 2022). After rehabilitation, they are released at

the centre's vulture restaurant. This may cause them to be disorientated, and far from their nesting sites. Additionally, the significant energy expenditure required to travel back to their nesting sites immediately after treatment could further compromise their weakened state, potentially resulting in mortality. These challenges highlight potential issues associated with reintroducing rehabilitated vultures into their natural habitat and highlight the need for comprehensive post-release monitoring.

After the initial decline in survival probability within the first 750 days post-release, the survival rates of wild and rehabilitated vultures become more comparable. Beyond this point, both groups exhibit similar patterns of survival, suggesting that once the rehabilitated vultures re-adapt to their natural environment, their survival rates align with those of wild vultures. This observation highlights the effectiveness of the rehabilitation process in preparing vultures for successful reintroduction.

Another important finding of our study was the number of vultures that were not reported again after tagging. For example, after tagging, 54% of rehabilitated vultures were not sighted again for a period longer than the 655-day threshold and are therefore presumed deceased. Similarly, 30% of wild vultures, post-tagging, have not been observed for a duration surpassing the 655-day threshold and are consequently presumed deceased. This is a concerning statistic as it indicates that the durability and reliability of tags may be lacking, causing them to fall off or break, or, more worryingly, the process of applying the tag or the tag itself is possibly negatively affecting the vultures. This was reported by Curk et al. (2021), who found that the flight of tagged Cape Vultures was hindered, and they flew shorter distances than those with leg rings. Further research is needed to investigate patagial tags' effect on vulture behaviour and survival, as it is presently common practice to use tags in vulture rehabilitation.

The observed drop to zero in survival curves for rehabilitated vultures after 1500 days could be attributed to data censorship, where some vultures may still be alive but were not observed beyond a certain point in the study period. This phenomenon does not necessarily indicate complete mortality among rehabilitated vultures. However, this pattern, which is not evident in the survival curves for wild vultures, raises important questions about the longevity of rehabilitated vultures compared to their wild counterparts. The lack of resighting data beyond a specific period could contribute to this observation. Further investigation is warranted to explore potential underlying reasons for any shorter survival durations in rehabilitated vultures and to assess the impact of data censorship on these findings.

Despite the potential impact of tags on vultures, it is essential to recognise the effectiveness of vulture rehabilitation in conservation efforts. While further research is needed to understand the implications of patagial tags on vulture behaviour and survival, rehabilitation remains a crucial tool in mitigating serious threats, such as poisoning, which poses a significant danger to vulture populations across Africa (Henriques et al., 2018; Murn & Botha, 2018; Deikumah, 2020; Freitas et al., 2020; Daboné et al., 2023b). Without intervention, the survival rate of injured or poisoned vultures would likely approach zero (Murn & Botha, 2018). Therefore, despite the challenges and limitations associated with rehabilitation, it remains a vital component of vulture conservation strategies.

The survival rates of both wild and rehabilitated vultures serve as indicators of the effectiveness of conservation efforts aimed at protecting these endangered species. Our study further demonstrated how rehabilitation centres play a vital role by providing critical care for vultures impacted by anthropogenic threats such as poisoning and injuries from collisions with energy infrastructure (Maphalala et al., 2021; Mashele et al., 2022). Conservationists can alter rehabilitation protocols and management practices by understanding factors affecting post-release survival to ensure the best chance of successful reintroduction. For example, identifying

the challenges faced by rehabilitated vultures during the initial stages of release, such as potential disorientation, reduced muscle mass, and, therefore, reduced flying and foraging abilities, can help with the development of targeted protocols aimed to enhance post-release survival.

4.5.3 Limitations and recommendations for future research

Despite several limitations, our study sheds light on the effectiveness of rehabilitation efforts for vulture conservation. All of the rehabilitated vultures in our dataset received treatment at Mohololoholo Wildlife Rehabilitation Centre, so it is important to acknowledge that the success of treatment and rehabilitation may vary across different rehabilitation centres. Factors such as the expertise of staff, available resources and rehabilitation protocols could influence the outcomes of rehabilitation efforts. Further studies comparing outcomes across multiple rehabilitation centres may help to better understand the effectiveness of vulture rehabilitation programs on a broader scale.

The small sample size in this study may have limited our ability to generalise our findings to the broader vulture population. With a limited number of vultures included in the analysis, there is a risk of sampling bias and reduced statistical power, which could affect the reliability of our results. Additionally, the small sample size of specific vulture species, including Cape Vultures, Hooded Vultures, Lappet-faced Vultures and White-headed Vultures, may have caused uncertainty in our estimates of dispersal distance and survival rates for these species. Future studies with larger sample sizes would provide more robust and representative findings about vulture populations and their behaviours.

The missing data on vulture age and causes of rehabilitation admissions is another important limitation of this study. To fully understand the factors influencing dispersal and survival rates, researchers should investigate vultures where their age and previous injuries are

known to provide more valuable insights into the factors affecting the success of vulture rehabilitation as a conservation tool.

While our study relies on tag-resighting reports to monitor vulture movements, it's important to note the potential limitations of this tracking method. The absence of sighting reports does not necessarily mean a vulture has died, as many people see patagial tagged vultures and do not report them (Laurieston et al., 2024) and tags can fall off or wear away over time, leading to underestimation of survival rates. We recommend researchers use global positioning systems (GPS) tracking devices to monitor vulture movements, as this is a more reliable method of monitoring and will allow for a more comprehensive understanding of vulture behaviour and survival post-release (Kendall & Virani, 2012; Krüger & Amar, 2017; Zvidzai et al., 2022).

The survival rates of vultures rehabilitated at Moholoholo Wildlife Rehabilitation Centre are similar to those of wild vultures, suggesting the effectiveness of the centre's rehabilitation protocols. However, we recommend rehabilitation facilities should minimise human interaction with vultures during treatment as much as possible to reduce any effects of stress (Wolter et al., 2019; Forbes, 2020). Also, rehabilitation centres should prioritise releasing vultures close to their original capture location to minimise potential disruptions and reduce immediate post-release energy expenditures. The use of flight tunnels may also be a method of increasing flight ability before release (African Raptor Centre, 2022). Additionally, supplementary feeding sites (SFSs) are proposed to reduce the number of vulture poisoning events (Gilbert et al., 2007; Brink et al., 2020). The safe provisioning of carcasses at SFSs should continue to be implemented across vulture habitats to support both rehabilitated and wild vultures and mitigate the risk of poisoning. This could in turn, decrease the number of vulture admissions to rehabilitation centres, ultimately avoiding any issues associated with the rehabilitation process. To conclude, while our study highlights the importance of rehabilitation

efforts in vulture conservation, continued research and proactive vulture conservation strategies are necessary to ensure the long-term viability of African vulture populations.

4.5.4 Conclusions

The findings presented here provide valuable insights into the historical trends and patterns of vulture tagging activities in southern Africa. The transition from leg rings to patagial tags reflects an evolution in tracking techniques aimed at enhancing monitoring capabilities. The collaboration between multiple vulture conservation organisations highlights the vital role of joint efforts in researching and protecting vultures across their habitats.

Our case study revealed that vulture rehabilitation can play an important role in preparing injured or poisoned vultures for successful reintroduction into the wild, demonstrating the effectiveness of rehabilitation efforts in conserving vulture populations. While patagial tags have proven invaluable in collecting long-term data on vulture movements, questions remain about their reliability and durability, which are crucial for future research and conservation efforts. Furthermore, the effectiveness of rehabilitation efforts in preparing vultures for successful reintroduction highlights the importance of comprehensive post-release monitoring and continued research into factors influencing vulture survival.

Moving forward, continued research and proactive conservation measures are essential to ensure the long-term viability of African vulture populations and to mitigate threats such as poisoning and habitat loss. Additionally, there is a critical need for further investigation into the potential effects of patagial tags on vulture fitness. Understanding the impact of tagging methods on vulture behaviour and survival is vital for informing conservation strategies and ensuring the ethical implementation of tagging practices. By addressing these issues, we can enhance our understanding of vulture ecology and improve conservation efforts aimed at safeguarding these important scavengers for future generations.

4.6 Acknowledgements

We are grateful to the University of KwaZulu-Natal (ZA) and the National Research Foundation (ZA, grant 98404) for funding. We are also grateful to the Rufford Foundation for its financial support.

4.7 References

African Raptor Centre. (2022). *Raptor Rescue*. https://africanraptor.co.za/homepage/raptor-rescue/

Bamford, A. J., Diekmann, M., Monadjem, A., & Mendelsohn, J. (2007). Ranging behaviour of Cape Vultures Gyps coprotheres from an endangered population in Namibia. *Bird Conservation International*, *17*(4), 331-339.

Batbayar, N., Reading, R., Kenny, D., Natsagdorj, T., & Kee, P. W. (2008). Migration and movement patterns of cinereous vultures in Mongolia. *Falco*, *32*(1), 5-7.

Brink, C. W., Santangeli, A., Amar, A., Wolter, K., Tate, G., Krüger, S., Tucker, A. S., & Thomson, R. L. (2020). Quantifying the spatial distribution and trends of supplementary feeding sites in South Africa and their potential contribution to vulture energetic requirements. *Animal Conservation*, *23*(5), 491-501.

Buechley, E. R., & Şekercioğlu, Ç. H. (2016). The avian scavenger crisis: Looming extinctions, trophic cascades, and loss of critical ecosystem functions. *Biological Conservation*, *198*, 220-228.

Champagnon, J., Guillemain, M., Elmberg, J., Massez, G., Cavallo, F., & Gauthier-Clerc, M. (2012). Low survival after release into the wild: assessing "the burden of captivity" on Mallard physiology and behaviour. *European Journal of Wildlife Research*, *58*, 255-267.

Cope, H. R., McArthur, C., Dickman, C. R., Newsome, T. M., Gray, R., & Herbert, C. A. (2022). A systematic review of factors affecting wildlife survival during rehabilitation and release. *PLoS One*, *17*(3), e0265514. https://doi.org/10.1371/journal.pone.0265514

Corlett, R. T., Primack, R. B., Devictor, V., Maas, B., Goswami, V. R., Bates, A. E., Koh, L. P., Regan, T. J., Loyola, R., & Pakeman, R. J. (2020). Impacts of the coronavirus pandemic on biodiversity conservation. *Biological Conservation*, *246*, 108571. https://doi.org/10.1016/j.biocon.2020.108571

Craig, C. A., Thomson, R. L., Girardello, M., & Santangeli, A. (2019). The drivers and extent of poison use by Namibia's communal farmers: Implications for averting the African vulture crisis. *Ambio*, *48*, 913-922.

Curk, T., Scacco, M., Safi, K., Wikelski, M., Fiedler, W., Kemp, R., & Wolter, K. (2021). Wing tags severely impair movement in African Cape Vultures. *Animal Biotelemetry*, *9*(1), 1-13.

Daboné, C., Ouéda, A., Adjakpa, J. B., & Weesie, P. D. (2023a). Breeding Behavior of the Hooded Vulture (*Necrosyrtes monachus*) in the Sudano-Sahelian Area (Garango, Burkina Faso). *Journal of Raptor Research, 57*(1), 30-43.

Daboné, C., Ouéda, A., Thompson, L. J., Adjakpa, J. B., & Weesie, P. D. (2023). Trade in vulture parts in West Africa: Burkina Faso may be one of the main sources of vulture carcasses. *Bird Conservation International*, *33*, e8. https://doi.org/10.1017/S095927092100054X

Deikumah, J. P. (2020). Vulture declines, threats and conservation: the attitude of the indigenous Ghanaian. *Bird Conservation International*, *30*(1), 103-116.

Department of Forestry, Fisheries and the Environment. (2024). *Kruger to Canyons Biosphere Reserve*. https://www.dffe.gov.za/kruger-canyons-biosphere-reserve

Forbes, N. A. (2020). Health, stress and welfare aspects of fitting research devices to vultures and condors. *Vulture News*, *78*(a), 8-11.

Fozzi, I., Brogi, R., Cavazza, S., Chirichella, R., De Rosa, D., Aresu, M., Cerri, J., Apollonio, M., & Berlinguer, F. (2023). Insights on the best release strategy from post-release movements and mortality patterns in an avian scavenger. *iScience*, *26*(5). https://doi.org/10.1016/j.isci.2023.106699

Freitas, R., Monteiro, C., Rodrigues, I., Tavares, A., Monteiro, G., Lopez, P., Martins, S., Ferreira, J., Lima, L., & Tavares, J. P. (2020). Cabo Verde Egyptian Vulture *Neophron percnopterus* on the brink: community perceptions, inferences and facts of an extreme population crash. *Bird Conservation International*, *30*(2), 289-307.

Gil, J., Díez, O., Báguena, G., Lorente, L., Pérez, C., Losada, J., & Alcántara, M. (2010). Juvenile dispersal of the bearded vulture (*Gypaetus barbatus*) in the Pyrenees (Spain-France). *Fundación para la Conservatión del Quebrantahuesos (FQC),* Spain.

Gilbert, M., Watson, R. T., Ahmed, S., Asim, M., & Johnson, J. A. (2007). Vulture restaurants and their role in reducing diclofenac exposure in Asian vultures. *Bird Conservation International*, *17*(1), 63-77.

Glucs, Z. E., Smith, D. R., Tubbs, C. W., Bakker, V. J., Wolstenholme, R., Dudus, K., Burnett, L. J., Clark, M., Clark, M., & Finkelstein, M. E. (2020). Foraging behavior, contaminant exposure risk, and the stress response in wild California condors (*Gymnogyps californianus*). *Environmental Research*, *189*, 109905. https://doi.org/10.1016/j.envres.2020.109905

Gore, M. L., Hübschle, A., Botha, A. J., Coverdale, B. M., Garbett, R., Harrell, R. M., Krüger, S. C., Mullinax, J. M., Olson, L. J., & Ottinger, M. A. (2020). A conservation criminology-based desk assessment of vulture poisoning in the Great Limpopo Transfrontier Conservation Area. *Global Ecology and Conservation*, *23*, e01076. https://doi.org/10.1016/j.gecco.2020.e01076

Green, R. E., Newton, I., Shultz, S., Cunningham, A. A., Gilbert, M., Pain, D. J., & Prakash, V. (2004). Diclofenac poisoning as a cause of vulture population declines across the Indian subcontinent. *Journal of Applied Ecology*, *41*(5), 793-800.

Hawkins, P. (2010). The welfare implications of housing captive wild and domesticated birds. In I. J. H. Duncan & P. Hawkins (Eds.*), The welfare of domestic fowl and other captive birds* (pp. 53-102). Springer, Dordrecht.

Henriques, M., Granadeiro, J. P., Monteiro, H., Nuno, A., Lecoq, M., Cardoso, P., Regalla, A., & Catry, P. (2018). Not in wilderness: African vulture strongholds remain in areas with high human density. *PLoS One*, *13*(1), e0190594. https://doi.org/10.1371/journal.pone.0190594

Houston, C. S., & Bloom, P. (2005). Turkey vulture marking history: the switch from leg bands to patagial tags. *North American Bird Bander*, *30*(2), 59-64.

IUCN. (2022). *Vultures,* IUCN Red List. https://www.iucnredlist.org/search?query=vulture&searchType=species

Ives, A. M., Brenn-White, M., Buckley, J. Y., Kendall, C. J., Wilton, S., & Deem, S. L. (2022). A global review of causes of morbidity and mortality in free-living vultures. *EcoHealth*, *19*(1), 40-54.

Jobson, B., Wolter, K., Jordan, L., Monadjem, A., & Rowcliffe, J. M. (2021). Home range and habitat selection of captive-bred and rehabilitated cape vultures *Gyps coprotheres* in southern Africa. *Oryx*, *55*(4), 607-612.

Kaplan, G. (2021). Casting the net widely for change in animal welfare: The plight of birds in zoos, ex situ conservation, and conservation fieldwork. *Animals*, *12*(1), 31.

Kendall, C. J., & Virani, M. Z. (2012). Assessing mortality of African vultures using wing tags and GSM-GPS transmitters. *Journal of Raptor Research*, *46*(1), 135-140.

Krüger, S., & Amar, A. (2017). Insights into post-fledging dispersal of Bearded Vultures *Gypaetus barbatus* in southern Africa from GPS satellite telemetry. *Bird Study*, *64*(2), 125-131.

Krüger, S., Reid, T., & Amar, A. (2014). Differential range use between age classes of southern African bearded vultures *Gypaetus barbatus*. *PLoS One*, *9*(12), e114920. https://doi.org/10.1371/journal.pone.0114920

Lagrange, P., Pradel, R., Bélisle, M., & Gimenez, O. (2014). Estimating dispersal among numerous sites using capture–recapture data. *Ecology*, *95*(8), 2316-2323.

Maphalala, M. I., Monadjem, A., Bildstein, K. L., Hoffman, B., & Downs, C. (2021). Causes of admission to a raptor rehabilitation centre and factors that can be used to predict the likelihood of release. *African Journal of Ecology*, *59*(2), 510-517.

Margalida, A., Carrete, M., Hegglin, D., Serrano, D., Arenas, R., & Donazar, J. A. (2013). Uneven large-scale movement patterns in wild and reintroduced pre-adult bearded vultures: conservation implications. *PLoS One*, *8*(6), e65857. https://doi.org/10.1371/journal.pone.0065857

Margalida, A., & Colomer, M. À. (2012). Modelling the effects of sanitary policies on European vulture conservation. *Scientific Reports*, *2*(1), 1-7.

Markandya, A., Taylor, T., Longo, A., Murty, M., Murty, S., & Dhavala, K. (2008a). Counting the cost of vulture decline—an appraisal of the human health and other benefits of vultures in India. *Ecological Economics*, *67*(2), 194-204.

Martens, F. R., Pfeiffer, M. B., Downs, C. T., & Venter, J. A. (2018). Post-fledging movement and spatial ecology of the endangered Cape Vulture (*Gyps coprotheres*). *Journal of Ornithology*, *159*, 913-922.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021). Uses of Vultures in Traditional Medicines in the Kruger to Canyons Biosphere Region, South Africa. *Journal of Raptor Research*, *55*(3), 328-339.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2022). Trends in the admission of raptors to the Moholoholo Wildlife Rehabilitation Centre, Limpopo Province, South Africa. *African Zoology*, *57*(1), 56-63.

Monadjem, A., Wolter, K., Neser, W., & Kane, A. (2014). Effect of rehabilitation on survival rates of endangered Cape vultures. *Animal Conservation*, *17*(1), 52-60.

Mundy, P. (1982). *The Comparative Biology of Southern African Vultures*. Vulture Study Group, Johannesburg.

Mundy, P., Butchart, D., Ledger J. and Piper, S. (1992). *The vultures of Africa*. Academic Press, London.

Murn, C., & Botha, A. (2018). A clear and present danger: impacts of poisoning on a vulture population and the effect of poison response activities. *Oryx*, *52*(3), 552-558.

Naidoo, V., Wolter, K., Espied, I., & Kotze, A. (2011). Vulture rescue and rehabilitation in South Africa: An urban perspective. *Journal of the South African Veterinary Association*, *82*(1), 24-31.

Ogada, D., Botha, A., & Shaw, P. (2016a). Ivory poachers and poison: drivers of Africa's declining vulture populations. *Oryx*, *50*(4), 593-596.

Ogada, D. L., Keesing, F., & Virani, M. Z. (2012a). Dropping dead: causes and consequences of vulture population declines worldwide. *Annals of the New York Academy of Sciences*, *1249*(1), 57-71.

Ogada, D., Shaw, P., Beyers, R. L., Buij, R., Murn, C., Thiollay, J. M., Beale, C. M., Holdo, R. M., Pomeroy, D., & Baker, N. (2016b). Another continental vulture crisis: Africa's vultures collapsing toward extinction. *Conservation Letters*, *9*(2), 89-97.

Ogada, D., Torchin, M., Kinnaird, M., & Ezenwa, V. (2012b). Effects of vulture declines on facultative scavengers and potential implications for mammalian disease transmission. *Conservation Biology*, *26*(3), 453-460.

Ottinger, M. A., Botha, A., & Bowerman, W. W. (2021). Global Challenges to Sustaining Vulture and Condor Populations. *Journal of Raptor Research*, *55*(3), 295-296.

Pennycuick, C. (1972). Soaring behaviour and performance of some East African birds, observed from a motor-glider. *Ibis*, *114*(2), 178-218.

Phipps, W. L., Wolter, K., Michael, M. D., MacTavish, L. M., & Yarnell, R. W. (2013). Do power lines and protected areas present a catch-22 situation for Cape vultures (*Gyps coprotheres*)? *PLoS One*, *8*(10), e76794. https://doi.org/10.1371/journal.pone.0076794

Primack, R. B., Bates, A. E., & Duarte, C. M. (2021). The conservation and ecological impacts of the COVID-19 pandemic. *Biological Conservation*, *260*, 109204. https://doi.org/10.1016/j.biocon.2021.109204

R Core Team. (2022). R: A language and environment for statistical computing (Version 4.2.1) [Software]. R Foundation for Statistical Computing.

Santangeli, A., Arkumarev, V., Komen, L., Bridgeford, P., & Kolberg, H. (2017). Unearthing poison use and consequent anecdotal vulture mortalities in Namibia's commercial farmland–implications for conservation. *Ostrich*, *88*(2), 147-154.

Shimelis, A., Sande, E., Evans, S., & Mundy, P. (2005). *International action plan for Lappet-faced Vulture, Torgos tracheliotus.* Birdlife International, Cambridge.

Spiegel, O., Getz, W. M., & Nathan, R. (2013). Factors influencing foraging search efficiency: why do scarce lappet-faced vultures outperform ubiquitous white-backed vultures? *American Naturalist*, *181*(5), E102-E115. https://doi.org/10.1086/670009

Wolter, K., Hirschauer, M., & Forbes, N. (2019). *Vulture Rehabilitation Manual*. VulPro NPC, South Africa. https://www.vulpro.com/wp-content/uploads/2020/02/Vulture-Rehabilitation-Manual-Version-2.0-1.pdf

Yee, N., Shaffer, L. J., Gore, M. L., Bowerman, W. W., & Harrell, R. M. (2021). Expert perceptions of conflicts in African vulture conservation: Implications for overcoming ethical decision-making dilemmas. *Journal of Raptor Research*, *55*(3), 359-373.

Zvidzai, M., Zengeya, F. M., Masocha, M., Ndaimani, H., & Murwira, A. (2022). Application of GPS occurrence data to understand African white-backed vultures *Gyps africanus* spatial home range overlaps. *Ecology and Evolution*, *12*(4), e8778. https://doi.org/10.1002/ece3.8778

CHAPTER 5

General discussion, conclusions and recommendations

5.1 Background

Vultures, comprising 23 species globally, are obligate scavengers and are crucial for ecosystem health. Their adaptations for scavenging, such as large wingspans and high stomach acidity, make them efficient in disposing of carcasses, nutrient cycling, and likely also preventing the spread of disease (Buechley & Şekercioğlu, 2016; Chen et al., 2023; Ogada et al., 2012; Santangeli et al., 2024).

Despite their ecological significance, vulture populations face severe threats globally, with 11 species classified as endangered or critically endangered. In Africa, six out of 11 vulture species are endangered or critically endangered, reflecting rapid population declines for most vulture species across the continent (IUCN, 2022). Unintentional poisoning, habitat loss because of urbanisation and agricultural expansion, and collisions with infrastructure are major threats (Zuberogoitia et al., 2008; Ogada et al., 2012; Reynolds et al., 2019; Ives et al., 2022). The 'Asian Vulture Crisis' highlighted the catastrophic consequences of poisoning, where populations plummeted because of unintentional poisoning with the veterinary drug Diclofenac (Ogada et al., 2016; Safford et al., 2019). Similar threats, including intentional poisoning for illegal wildlife trade and cultural practices, also threaten African vultures (Otieno et al., 2011; Mashele et al., 2021a,b; Manqele et al., 2023).

Conservation efforts to protect African vultures include a range of strategies aimed at mitigating threats and promoting population recovery (National Vulture Task Force, 2022). These efforts encompass monitoring, education, captive breeding, and habitat conservation. Initiatives such as International Vulture Awareness Day raise public awareness and support for vulture conservation (Department of Forestry, Fisheries and the Environment, 2023). Captive

breeding and monitoring programs, like the Bearded Vulture Recovery Programme, play a vital role in conserving threatened species (African Raptor Centre, 2022). Additionally, in establishing Vulture Safe Zones, conservationists collaborate with landowners to reduce threats and secure vulture-friendly habitats (Kane et al., 2022). Poison response training equips field staff to address poisoning incidents and mitigate vulture fatalities effectively (Department of Forestry, Fisheries and the Environment, 2023). Tagging and marking programs provide valuable data on vulture movements and behaviour for conservation planning (Wilson, 2015; Curk et al., 2021; National Vulture Task Force, 2022). Rehabilitation and release programs contribute to population recovery by rescuing and treating injured vultures (Naidoo et al., 2011; Monadjem et al., 2014; Maphalala et al., 2021; Mashele et al., 2022). The range of conservation initiatives in place highlights the need for diverse strategies to address the numerous challenges faced by vultures throughout Africa.

5.2 Summary of findings

This research project examined various conservation strategies implemented in South Africa to protect vulture populations. Each study provided valuable insights into different aspects of vulture conservation. By evaluating these strategies, the studies contribute to our understanding of the challenges and opportunities in vulture conservation.

The systematic review of global questionnaire-based vulture research confirmed our prediction, demonstrating that this method is effective in collecting valuable data on vulture ecology and conservation. The review uncovered key insights into public perceptions, attitudes, and the significant threats facing vulture populations, as anticipated (Chapter 2). Notably, these studies, spanning 38 countries and engaging participants from diverse backgrounds, have brought attention to critical issues such as the widespread misconception among farmers that vultures prey on their livestock. This misconception not only fuels negative attitudes towards

vultures but also exacerbates retaliatory killings and poisoning incidents, posing significant threats to vulture populations (Ballejo et al., 2019; Shiferaw et al., 2022). These results highlight the urgent necessity for focused actions to counter the growing threats to vultures across various regions globally. Specifically, in Africa, the research reveals alarming trends of intentional poisoning and poaching for trade and traditional medicine (Mashele et al., 2021a; 2021b), highlighting critical challenges facing vulture populations in this region (Chapter 2).

We used in person and online questionnaires to explore the public perceptions and awareness regarding wildlife marking techniques, with a specific emphasis on patagial tags on African vultures (Chapter 3). As predicted, there was a predominantly positive attitude towards the marking of wildlife among the stakeholder groups, including conservation professionals, field guides, wildlife photographers, international tourists and locals. Participants showed a high awareness of common marking methods like tracking collars and patagial tags, but had some gaps in fully understanding their purposes, indicating the need for ongoing education. Attitudes towards encountering marked wildlife were generally positive, though concerns about animal welfare, especially regarding the size of tagging devices and possible effects on the animal's welfare, were raised. Field guides were enthusiastic about discussing conservation efforts, while wildlife photographers had mixed feelings about photographing tagged vultures because of aesthetic concerns. Participants unanimously recognised vultures' ecological importance and expressed concerns about declining populations, which they attributed to factors like poisoning, habitat loss, and use in traditional medicine. There was broad support for the patagial tagging of vultures, but engagement and reporting of tagged vultures varied among participant groups, emphasising the importance of raising awareness of these monitoring programmes (Chapter 3).

The analysis of the Endangered Wildlife Trust's Vulture Resighting Database highlighted the collaborative nature of vulture conservation in this region, with vulture tagging

initiatives employed in seven countries in southern Africa by various vulture conservation organisations (Chapter 4). Patagial tags have proven valuable in collecting long-term data on vulture movements, but the study highlights concerns about the reliability and durability of tagging methods. The high number of vultures not resighted after tagging raises questions about potential impacts on vulture behaviour and survival. Our case study revealed that vultures treated at Moholoholo Wildlife Rehabilitation Centre were surviving at a similar rate to wild vultures, indicating that the rehabilitation process is successful in reintroducing poisoned and injured vultures into the wild. This finding supports the null hypothesis (H0), which stated that there would be no significant difference in post-release outcomes between rehabilitated and wild-caught vultures. The prediction that rehabilitated vultures would show comparable post-release dispersal distances and survival rates to wild-caught vultures was also confirmed. This suggests that the rehabilitation efforts are effective in achieving similar post-release success as that of wild vultures. However, rehabilitated vultures tended to disperse further from their tagging locations, potentially because of their release at a supplementary feeding site far from their original capture location. While rehabilitation centres play a vital role in vulture conservation, challenges such as post-release mortality and behavioural impacts of tagging methods require further investigation (Chapter 4).

5.3 Recommendations

Increased awareness and public engagement are crucial recommendations stemming from questionnaire-based vulture research. These studies have highlighted the importance of communicating the urgency of vulture conservation issues to diverse stakeholders, including farmers, local communities, and conservationists. Tailored conservation strategies should be developed based on the insights gained from these studies to address specific challenges faced by vulture populations globally. For instance, in regions where vulture populations are

threatened by poisoning incidents from the misuse of pesticides or veterinary drugs, conservation efforts should focus on implementing stricter regulations and control measures to limit the availability of these harmful substances. Educational outreach programmes targeting farmers and veterinary practitioners could be designed to raise awareness about the ecological consequences of chemical misuse and promote safer practices. Furthermore, community-based programmes could incentivise responsible carcass disposal and discourage the use of poisoned baits. By customising conservation strategies to combat the unique threats faced by vulture populations across different regions, stakeholders can collaborate more effectively to mitigate these challenges and safeguard vultures in their natural habitats. Understanding the intricate dynamics between vultures and humans is essential for designing impactful conservation initiatives, which should involve fostering partnerships with local communities and other stakeholders to garner greater support for vulture conservation efforts. Additionally, promoting positive attitudes towards vultures and offering economic incentives, such as avian-based tourism, can further motivate local communities to actively participate in conservation efforts.

Several recommendations can be made from the study regarding public perceptions of marking wildlife for research and conservation purposes. Firstly, targeted educational campaigns should be developed to increase awareness among all stakeholder groups about the importance of vulture marking techniques, and their role in wildlife research and conservation. These campaigns should emphasise the various purposes of marking wildlife, including tracking movements, ecological research, anti-poaching efforts, wildlife rehabilitation, and identifying threats and causes of mortality. Additionally, efforts should be made to address concerns related to animal welfare by providing transparent information about the procedures followed to minimise discomfort during marking. Collaboration with local communities is essential to foster mutual understanding and cooperation, particularly in regions where cultural practices involving vulture body parts pose challenges to conservation efforts. Moreover,

proactive measures should be taken to promote active participation in reporting sightings of patagial tagged vultures, including targeted outreach to tourists, wildlife photographers, and local communities. By implementing these recommendations, stakeholders can work together to raise awareness, promote positive attitudes, and encourage greater engagement in vulture conservation initiatives.

Regarding the evaluation of rehabilitation and release as a vulture conservation tool, efforts should prioritise enhancing the rehabilitation process for vultures by minimising stress and reducing the duration of captivity, while simultaneously optimising the physical strength and fitness of the birds. This can be achieved by implementing protocols that ensure appropriate and sanitary housing conditions, minimising human contact to prevent habituation, and providing sufficient space for exercise and natural behaviours. By prioritising these aspects of rehabilitation, vultures can be better prepared for successful release back into their natural habitats, contributing to the overall effectiveness of conservation efforts.

5.4 Future research

Tailored conservation strategies should be developed based on the insights gained from questionnaire-based vulture research to address the specific challenges faced by vulture populations globally effectively. Future research should prioritise conducting questionnaire-based studies in countries where vultures inhabit but have not yet been studied. This approach would provide a comprehensive understanding of local perceptions, threats, and conservation needs across different regions. Additionally, there is a pressing need to focus on understudied vulture species, particularly those with critical conservation status, to develop targeted and effective conservation strategies. By expanding research to these areas and species, we can better inform conservation efforts and create more nuanced and effective management plans that address the unique challenges faced by vulture populations globally. Moreover, future

research should aim to include underrepresented stakeholder groups to deepen the insights gained. Despite their crucial perspectives on conservation challenges and strategies, key groups such as law enforcement officials, government representatives, ornithologists, conservationists, tourist centre staff, rangers, and cultural or religious authorities have been involved in only a few studies. By expanding the inclusion of these stakeholders, future research can develop a more comprehensive understanding of the diverse factors influencing vulture conservation and enhance the effectiveness of conservation efforts. This holistic approach will not only enrich our knowledge base but also foster stronger collaboration and support for vulture conservation initiatives worldwide.

In continuation of the study's findings on public awareness and perception of wildlife marking techniques, future research should focus on several key areas to advance vulture conservation and public engagement. Long-term studies are needed to assess the impact of educational campaigns over time. Innovative approaches, such as citizen science projects, a mobile app, and signage in national parks, can enhance public participation in reporting sightings of patagial tagged vultures. Additionally, research on socio-cultural factors influencing public perceptions can inform more effective conservation strategies. By addressing these gaps, researchers can develop evidence-based approaches to safeguard vulture populations and promote broader public involvement in conservation efforts.

In future vulture conservation research, it is crucial to prioritise studies focusing on the effectiveness of rehabilitation protocols and minimising stress on rehabilitated vultures. It is essential to investigate methods to ensure that vultures are fit and strong enough for release without losing significant muscle mass or becoming reliant on provisioned food during their time in captivity. Additionally, using GPS devices for tracking vultures can significantly enhance monitoring efforts, providing seamless data collection without relying solely on sightings and reports (Iredale et al., 2010). These advancements in tracking technology can

offer more accurate and comprehensive insights into vulture behaviour and movements, ultimately improving conservation strategies and outcomes for this ecologically vital group of birds.

Future research can significantly enhance vulture conservation efforts by integrating tailored conservation strategies, innovative public engagement methods, and advanced tracking technologies. These comprehensive approaches will be instrumental in ensuring the sustainable recovery and long-term preservation of vulture populations globally.

5.5 References

African Raptor Centre. (2022). *The Bearded Vulture Breeding Program*. https://africanraptor.co.za/homepage/the-bearded-vulture-conservation-project/

Ballejo, F., Grilli, M. G., & Lambertucci, S. A. (2019). A long and troublesome journey: People's perceptions and attitudes along the migratory path of a scavenger bird. *Ethnobiology and Conservation*, *8*, 13. https://doi.org/10.15451/ec2019-10-8.13-1-13

Buechley, E. R., & Şekercioğlu, Ç. H. (2016). The avian scavenger crisis: Looming extinctions, trophic cascades, and loss of critical ecosystem functions. *Biological Conservation*, *198*, 220-228.

Chen, Y., Xiang, L., Chen, P., & Zhao, H. (2023). Vultures as a model for testing molecular adaptations of dietary specialization in birds. *Avian Research*, *14*, 100128. https://doi.org/10.1016/j.avrs.2023.100128

Curk, T., Scacco, M., Safi, K., Wikelski, M., Fiedler, W., Kemp, R., & Wolter, K. (2021). Wing tags severely impair movement in African Cape Vultures. *Animal Biotelemetry*, *9*(1), 1-13.

Department of Forestry, Fisheries and the Environment. (2023). *Forestry, Fisheries and the Environment marks International Vulture Awareness Day 2023*. https://www.gov.za/news/media-statements/forestry-fisheries-and-environment-marks-international-vulture-awareness-day

Iredale, S. K., Nevill, C. H., & Lutz, C. K. (2010). The influence of observer presence on baboon (*Papio spp*.) and rhesus macaque (*Macaca mulatta*) behavior. *Applied Animal Behaviour Science*, *122*(1), 53-57.

IUCN. (2022). *Vultures,* IUCN Red List. https://www.iucnredlist.org/search?query=vulture&searchType=species

Ives, A. M., Brenn-White, M., Buckley, J. Y., Kendall, C. J., Wilton, S., & Deem, S. L. (2022). A global review of causes of morbidity and mortality in free-living vultures. *EcoHealth*, *19*(1), 40-54.

Kane, A., Monadjem, A., Aschenborn, H. O., Bildstein, K., Botha, A., Bracebridge, C., Buechley, E. R., Buij, R., Davies, J. P., & Diekmann, M. (2022). Understanding

continent-wide variation in vulture ranging behavior to assess feasibility of Vulture Safe Zones in Africa: Challenges and possibilities. *Biological Conservation*, *268*, 109516. https://doi.org/10.1016/j.biocon.2022.109516

Manqele, N. S., Selier, S. J., & Downs, C. T. (2023). The ethnomedicinal use of vultures by traditional health practitioners in KwaZulu-Natal, South Africa. *Journal of Ornithology*, *164*(4), 777-788.

Maphalala, M. I., Monadjem, A., Bildstein, K. L., Hoffman, B., & Downs, C. (2021). Causes of admission to a raptor rehabilitation centre and factors that can be used to predict the likelihood of release. *African Journal of Ecology*, *59*(2), 510-517.

Markandya, A., Taylor, T., Longo, A., Murty, M., Murty, S., & Dhavala, K. (2008). Counting the cost of vulture decline—an appraisal of the human health and other benefits of vultures in India. *Ecological Economics*, *67*(2), 194-204.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021a). Traditional health practitioners' and other community members' perceptions of vultures in the Kruger to Canyons biosphere region, South Africa. *Journal of Raptor Research*, *55*(3), 340-358.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2022). Trends in the admission of raptors to the Mohololoholo Wildlife Rehabilitation Centre, Limpopo province, South Africa. *African Zoology*, *57*(1), 56-63.

Mashele, M. N., Thompson, L. J., & Downs, C. T. (2021b). Uses of vultures in traditional medicines in the Kruger to Canyons Biosphere Region, South Africa. *Journal of Raptor Research*, *55*(3), 328-339.

Monadjem, A., Wolter, K., Neser, W., & Kane, A. (2014). Effect of rehabilitation on survival rates of endangered Cape vultures. *Animal Conservation*, *17*(1), 52-60.

Naidoo, V., Wolter, K., Espied, I., & Kotze, A. (2011). Vulture rescue and rehabilitation in South Africa: An urban perspective. *Journal of the South African Veterinary Association*, *82*(1), 24-31.

National Vulture Task Force. (2022). *Draft Biodiversity Management Plan (BMP) for the Conservation of Seven Vulture Species in South Africa*. (47632). South Africa: Government Gazette.

Ogada, D., Keesing, F., & Virani M, Z. (2012). Dropping dead: causes and consequences of vulture population declines worldwide. *Annals of the New York Academy of Sciences*, *1249*(1), 57-71.

Ogada, D., Shaw, P., Beyers, R. L., Buij, R., Murn, C., Thiollay, J. M., Beale, C. M., Holdo, R. M., Pomeroy, D., & Baker, N. (2016). Another continental vulture crisis: Africa's vultures collapsing toward extinction. *Conservation Letters*, *9*(2), 89-97.

Otieno, P. O., Lalah, J. O., Virani, M., Jondiko, I. O., & Schramm, K.-W. (2011). Carbofuran use and abuse in Kenya: Residues in soils, plants, water courses and the African white-backed vultures (*Gyps africanus*) found dead. *The Environmentalist*, *31*, 382-393.

Reynolds, J., Ibáñez-Álamo, J. D., Sumasgutner, P., & Mainwaring, M. C. (2019). Urbanisation and nest building in birds: A review of threats and opportunities. *Journal of Ornithology*, *160*(3), 841-860.

Safford, R., Andevski, J., Botha, A., Bowden, C. G., Crockford, N., Garbett, R., Margalida, A., Ramírez, I., Shobrak, M., & Tavares, J. (2019). Vulture conservation: The case for urgent action. *Bird Conservation International*, *29*(1), 1-9.

Santangeli, A., Lambertucci, S. A., Margalida, A., Carucci, T., Botha, A., Whitehouse-tedd, K., & Cancellario, T. (2024). The global contribution of vultures towards ecosystem services and sustainability–an experts' perspective. *iScience*, *27*, 109925. https://doi.org/10.1016/j.isci.2024.109925

Shiferaw, B., Bekele, A., & Afework, B. (2022). Population status of the Critically Endangered African White-Backed Vultures (*Gyps africanus*) in and around Wolkite town, Southwestern Ethiopia. *SINET: Ethiopian Journal of Science*, *45*(3), 359-368.

Wilson, B. (2015). An introduction to camera trapping of wing-tagged vultures in southern Africa. *Vulture News*, *69*, 3-22.

Zuberogoitia, I., Zabala, J., Martínez, J., Martínez, J., & Azkona, A. (2008). Effect of human activities on Egyptian vulture breeding success. *Animal Conservation*, *11*(4), 313-320.