Aspects of the ecology and persistence of vervet monkeys in mosaic urban landscapes in KwaZulu-Natal, South Africa

Kerushka Robyn Pillay

Submitted in fulfilment of the academic requirements for the degree of

Doctor of Philosophy

in the Discipline of Ecological Sciences

School of Life Sciences

College of Agriculture, Engineering and Science

University of KwaZulu-Natal

Pietermaritzburg Campus

2022

ABSTRACT

The geological era in which we live is termed the Anthropocene and is causing the greatest loss of biodiversity and species brought on by a single species: *Homo sapiens*. The human population places great demands on the environment, altering and modifying it to suit people's needs. Urbanisation is one of the greatest anthropogenic land-use modifications, predominantly for infrastructure and housing developments. This results in the loss of natural green spaces where wildlife lives, forcing them into smaller fragmented habitats, often having to share the urban mosaic landscape with humans. These increased interactions often lead to human-wildlife conflict. Generally, urbanisation affects species negatively. However, some species exhibit the ability to persist in urban areas, successfully utilising resources for their natural life traits. One such primate species persisting in urban mosaic landscapes is the vervet monkey, *Chlorocebus pygerythrus,* particularly in the eThekwini Municipality, Durban, KwaZulu-Natal Province, South Africa. Increased human population growth and associated urban transformation have increased contact between humans and troops of vervet monkeys using residential and industrial gardens. This has led to increased human-wildlife conflict, with vervet monkeys often persecuted because of their damage to human property and harassment. Little is known about the ecology of urban vervet monkeys, so to assess and manage this wildlife conflict, a need to determine the behavioural ecology and persistence of vervet monkeys were investigated in this study. This study analysed vervet monkeys' spatial ecology in the mosaic urban-forest landscape and provided insight into their home ranges and habitat use here. Additionally, the effects of anthropogenic activities and human-wildlife conflict on wild vervet monkeys were documented. The results contribute to understanding the foundation of human-vervet conflict resolution programmes and support for further education and coexistence with wildlife in mosaic urban landscapes. The conservation of vervet monkeys should be supported by all who live in these areas, not by some factions. The presence of

primates, such as the vervet monkey, that use managed green spaces, such as gardens, in the eThekwini Municipality should provide the public with the ultimate catalyst and insight into protecting and conserving this species and others for future generations. Overall, the results presented in this thesis provide an understanding of the persistence of this Old World primate in mosaic urban landscapes.

PREFACE

The data described in this thesis were collected in Durban, KwaZulu-Natal Province, the Republic of South Africa, from October 2016 to December 2020. 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.

This thesis, submitted for the degree of Doctor of Philosophy 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 and the results reported are because of investigations by the candidate.

.....

Kerushka R. Pillay
March 2022

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
March 2022

COLLEGE OF AGRICULTURE, ENGINEERING, AND SCIENCE

DECLARATION 1 - PLAGIARISM

I, Kerushka R. Pillay, 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 being detailed in the thesis and in the References sections.

Signed: .....

Kerushka R. Pillay

March 2022

COLLEGE OF AGRICULTURE, ENGINEERING, AND SCIENCE

DECLARATION 2 - PUBLICATIONS

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

Publication 1 - in review

Pillay, KR Streicher, J.P. and Downs C.T.

Home range and habitat use of vervet monkeys in the urban forest mosaic landscape of Durban, eThekwini Municipality, KwaZulu-Natal, South Africa

Author contributions:

KRP conceived paper with CTD and JPS. KRP collected and analysed data, and wrote the draft paper. CTD and JPS contributed valuable comments to the manuscript.

Publication 2

Pillay, KR and Downs C.T.

Surviving the urban jungle - vervet monkeys facing human-wildlife conflict in South Africa

Author contributions:

KRP conceived paper with CTD. KRP collected and analysed data, and wrote the paper. CTD contributed valuable comments to the manuscript.

Publication 3

Pillay, KR and Downs C.T.

Pregnancy complications in wild vervet monkeys in the urban mosaic landscape

Author contributions:

KRP conceived paper with CTD. KRP collected and analysed data, and wrote the paper. CTD contributed valuable comments to the manuscript

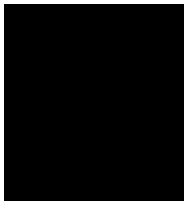
Publication 4

Pillay, KR and Downs C.T.

Media framing of vervet monkeys: implications for human-wildlife interactions in South Africa

Author contributions:

KRP conceived paper with CTD. KRP collected and analysed data, and wrote the paper. CTD contributed valuable comments to the manuscript.



Signed: ……

Kerushka R. Pillay

March 2022

ACKNOWLEDGEMENTS

Firstly, I am grateful to my supervisor Prof Colleen T. Downs, for her unwavering support, wisdom, and motivation. Her constant belief in me and my research abilities propelled me to complete this project. I want to thank the following funding sources: The National Research Foundation (ZA), the Durban Research Action Partnership (ZA), and the University of KwaZulu-Natal (ZA) for their financial support, which made this project possible. I am grateful to the Centre for Rehabilitation of Wildlife (CROW) staff, the Buffelsdraai Regional Landfill Site, WESSA Treasure Beach, Mr Victor Hugo from Animal Trackem, and veterinarian, Dr Sanil Singh, for their technical knowledge and assistance during fieldwork. I am truly thankful for having them on call to answer any questions. A special thank you to the postgrads of the UKZN Down's Lab who assisted with fieldwork, data collection and statistical dilemmas. My sincere appreciation goes to my 'Maritzburg friends' Priyanka Pachuwah, Vuyisile Thabethe, and Devashan Naidoo, for their kindness and friendship over the years. To my surrogate parents, May and Rory Whitfeld, I am thankful for your warm-heartedness and for providing me with a "home away from home". I am most grateful to my mother, Pavanee Pillay, and my late father, Links Pillay. Without their sacrifices, guidance, and confidence in me, I would not be where I am today. I thank them from the bottom of my heart for encouraging me from a young age to pursue my dreams in the Natural Sciences. I am most grateful to my husband, Prebashan Reddy, for his consistent devotion and encouragement in motivating me to fulfil my goals, even at my lowest point. Finally, a special thanks to the vervet monkeys of Durban, who continue to show resilience and wit towards the human-modified landscape while adapting to the urban jungle.

Juvenile vervet monkey (*Chlorocebus pygerythrus*) with half a tail in KwaZulu-Natal, South Africa (Photo credit KR Pillay 2017)

கல்வியே அழிவு இல்லாத சிறந்த செல்வம்;

பிற எல்லாம் செல்வமே அல்ல.

Learning is excellence of wealth that none destroy;

To man nought else affords reality of joy.

- Tirukkuṟaḷ 400

Dedicated to the memory of Links, Bala, and Lali Pillay

TABLE OF CONTENTS

FIGURES

TABLES

CHAPTER 1

Introduction

1.1 Background

Humans have, through several factors, altered primate habitats drastically over several decades, leading to several species becoming threatened (Mittermeier et al., 2009; Schwitzer et al., 2011). For instance, the exponential growth of the human population during the Anthropocene has placed tremendous pressure on ecosystems, directly impacting wild primate numbers (Kalbitzer and Chapman, 2018). Furthermore, overpopulation has contributed to factors affecting environmental health that have been silent driving forces behind habitat and species loss (Crist et al., 2017). Present threats to primate populations have increased because of habitat loss, bushmeat hunting, disease, and climate change (Chapman and Gogarten, 2012). Accelerating rates of anthropogenic activity have caused habitat destruction, which leads to land degradation and fragmentation, resulting in a reduction in environmental quality for primates (Estrada et al., 2017). The removal and harvesting of natural land for human demands, particularly for agriculture, urbanisation and industrial production, including logging, mining, and urban sprawl, severely degrade habitats (Satterthwaite et al., 2010; Estrada et al., 2012; Singh and Singh, 2017). The effects of habitat fragmentation exacerbate habitat loss. Habitat loss reduces the overall area in which primates can survive, whereas habitat fragmentation divides large contiguous habitats into smaller isolated patches (Ewers and Didham, 2006; Arroyo-Rodríguez et al., 2013). Also, the construction of linear infrastructure for urban development further impacts fragmentation and the isolation of primate populations (Ascensão et al., 2021). Arboreal, forest-dwelling primates are most sensitive to human-induced habitat fragmentation that threatens their behavioural and dispersal mechanisms because of these isolated forest patches (Banks et al., 2007; Arroyo-Rodríguez and Mandujano, 2009). On the

other hand, semi-terrestrial, terrestrial, or habitat generalist species can adapt their needs to the available resources from disturbed areas (Galán-Acedo et al., 2019).

Forest mammals like primates living in urban-rural landscape mosaics are most vulnerable to anthropogenic activities (Zungu et al., 2020b). Although the literature suggests general negative implications for primate species in human-modified landscapes worldwide (Estrada et al., 2012; de Almeida-Rocha et al., 2017; Galán-Acedo et al., 2019; Galán-Acedo et al., 2019), some primates have displayed adaptability, exhibiting generalist species traits that have shown persistence for resources under various levels of anthropogenic pressures (Hoffman and O'Riain, 2012; Nowak and Lee, 2013; Hockings et al., 2015; McLennan et al., 2017; Santini et al., 2019). Certain primate species like macaques (*Macaca tonkeana*) (Riley, 2007), spider monkeys (genus *Ateles*) (Arroyo-Rodríguez et al., 2017), and langurs (*Trachypithecus pileatus*) (Borah et al., 2021); flourish and demonstrate resilience by exploiting human-modified landscapes by shifting their natural behaviour in terms of spatial, dietary, and breeding ecology. Therefore, it is important that an understanding of the responses of primates to anthropogenic pressures is generated for the effective conservation of primate populations.

1.2 Human-wildlife conflict

Human-wildlife conflict is one of the greatest threats to wildlife species and occurs when negative interactions occur between humans and wildlife, often competing for limited resources in a shared landscape (Sillero-Zubiri and Switzer, 2001; Nyhus, 2016; Bruskotter et al., 2017). Wildlife conflicts can have adverse effects on humans that can be direct or indirect. Direct impacts on humans occur when wildlife poses a threat to human life, during wildlife collisions with vehicles or through the transmission of parasitic or zoonotic diseases (Nyhus, 2016). Additionally, wildlife conflict can directly impact economic loss to crops, livestock,

domestic pets, and property damage (Treves and Karanth, 2003; Peterson et al., 2010; Manral et al., 2016; Schell et al., 2021). Indirect impacts include disruption of livelihoods, food insecurity, opportunity costs to farmers and diminished psychosocial wellbeing (Thirgood and Woodroffe, 2005; Dickman, 2010; Barua et al., 2013; Anand and Radhakrishna, 2017). People often respond negatively to human-wildlife conflict, causing them to kill wildlife in self-defence or as pre-emptive or retaliatory killings (Gross et al., 2021). If human-wildlife conflict is not effectively managed, we could lose abundant species or cause the extinction of threatened or vulnerable species.

Human-wildlife conflict is not limited to rural locations or developing countries but occurs throughout the world (Distefano, 2005). This phenomenon also takes place in urban areas where humans and wildlife share a common space (Soulsbury and White, 2015). Urbanisation is increasing the interaction between humans and wildlife as the area they exist in becomes crowded, thereby creating more opportunities for humans to encounter wildlife leading to human-wildlife conflict (Schell et al., 2021). Globally, the case studies of human-wildlife conflict have been documented in urban areas, and these included birds (Charles and Linklater, 2013; Boal and Dykstra, 2018; Kumar et al., 2019); reptiles (Gayen et al., 2019; Ingle et al., 2019); and carnivore species (Elliot et al., 2016; Moss et al., 2016; Bombieri et al., 2018; van Bommel et al., 2020). Urban mammalian species include coyotes (*Canis latrans*) (Murray et al., 2015); brushtail possum *(Trichosurus vulpecula)* and ringtail possum *(Pseudocheirus peregrinus)* (Hill et al., 2007); white-tailed deer (*Odocoileus virginianus*) (Storm et al., 2007); and non-human primates, hereafter primates (Rodrigues and Martinez, 2014; Corrêa et al., 2018; Uddin et al., 2020; Nunes et al., 2021). Human-wildlife conflict will intensify as urban sprawl encroaches on wildlife habitats. To reduce human-wildlife conflict, there is a need to reassess the relationships between humans and wildlife to improve coexistence.

1.2.1 Human-primate conflict

Human-primate conflict as a subset of human-wildlife conflict occurs when humans and primates interact for the same resources. Hockings (2016) defines human-primate conflict as "any human-primate interaction which results in negative effects on human social, economic or cultural life, primate social, ecological or cultural life or the conservation of primates and their environment". The encroachment of humans onto primate habitats increases the interactions between people and primates, leading to widespread conflicts (Estrada et al., 2017). Primates that live close to communities can impose costs directly on people (Hill, 2002).

Several reported drivers of conflict were previously reported and include crop-raiding events, destruction of property, aggression towards humans and pets and disease transmission (Fedigan, 2010; Fuentes, 2012; Hockings, 2016; Bloomfield et al., 2020). The biggest driver of human-primate conflict is crop raiding, when primates forage on agriculturally important crops. Several studies have observed conflict between humans and primates, and this has been observed in various locations around the world. In Asia, conflict was observed in species of orangutans (*Pongo* spp.) for subsistence farmed crops and oil palm (Swarna and Tisdell, 2009; Meijaard et al., 2011). The macaque species, particularly Buton macaques (*Macaca ochreata brunnescens*), rhesus macaque (*Macaca mulatta*), and bonnet macaque (*Macaca radiata*), were also in conflict with people because of crop-raiding events (Priston et al., 2012; Anand et al., 2018). Africa also experienced crop-raiding by olive baboons (*Papio anubis*), patas monkeys (*Erythrocebus patas*), green monkeys (*Cercocerbus sabaeus*), chimpanzees (*Pan troglodytes)* and baboons (*Papio* spp*.)* (Tweheyo et al., 2005; Wallace and Hill, 2012; Wiafe, 2019).

1.2.2 Human-vervet conflict

Remarkably, macaques, baboons, and vervet monkeys (*Chlorocebus* spp.) belonging to the Cercopithecoid group are represented as crop raiders in the primate crop foraging literature

(Hill, 2018). Crop raiding by *Chlorocebus* spp. causes massive seasonal economic losses ranging from $80-400 USD in 2001 (Saj et al., 2001). Throughout Africa, vervet monkeys are considered "pest" species because of the frequency and intensity of foraging incidents on crops (Hill, 1997; Naughton-Treves et al., 1998; Sillero-Zubiri and Switzer, 2001; Chapman et al., 2016; Cancelliere et al., 2018; Alemayehu and Tekalign, 2020). Historically, *Chlorocebus* spp. was documented feeding on non-natural food from tourists and also exhibited intergroup aggression in South Africa and Kenya (Basckin and Krige, 1973; Brennan et al., 1985). In South Africa, three primate species occur, and all have adapted to exploit human resources. These are the chacma baboon (*Papio ursinus*) (van Doorn and O'Riain, 2020), the samango monkey (*Cercopithecus albogularis schwarzi*) (Parker et al., 2021) and the vervet monkey (*Chlorocebus pygerythrus*) (Forss et al., 2021).

Recognised as a semi-terrestrial and generalist species, the vervet monkey is one primate that has presented radical ecological flexibility. Vervet monkeys exist in anthropogenically disturbed ranges which include farmlands, fragmented forests, isolated protected areas, and human settlements (Chapman et al., 2006). Vervet monkeys are not deterred by fragmented or degraded landscapes and have adapted successfully to human-modified landscapes especially urban areas (Cancelliere et al., 2018). Vervet monkeys display behavioural elasticity, have adapted particularly well to urbanisation, and can be classified as urban adapters (Thatcher et al., 2020; Van Helden et al., 2020). Furthermore, vervet monkeys can be described as urban foragers since the species has been witnessed foraging from bird feeders, refuse and garbage bins, on food items from restaurants, homes, and gardens, pet bowls, or by direct feeding by people (Patterson et al., 2018; Thatcher et al., 2019; Fehlmann et al., 2021). Due to this foraging modification by vervet monkeys in urban areas, there has been an increased frequency and contact between humans resulting in human-vervet conflict. Subsequently, the lack of natural predators of vervet monkeys allows them to move without

restraint which has also put them at risk of human-induced activities in urban areas (Isbell and Young, 1993; Thatcher et al., 2019; LaBarge et al., 2020). Reports from the public and frequent news reports on vervet monkeys injured through vehicle accidents, shootings, poisonings, pet attacks and being kept as pets were directly observed before this study (pers. comm.). The conflict between human residents and wildlife is a global phenomenon, and management solutions to these problems differ between countries and cities (Grimm et al., 2000).

1.3 Study species

1.3.1 Taxonomy and distribution of vervet monkeys

The vervet monkey, *Chlorocebus pygerythrus* (F. Cuvier, 1821), is one of the most common and abundant primates native to southern Africa. It has the synonym, *Cercopithecus pygerythrus* (Cuvier, 1821), with common names in South African languages called: Blouaap (Afrikaans), Kgabo (Sepedi, Sesotho, Tswana) and Inkawu (Xhosa, Zulu). *Chlorocebus pygerythrus* is treated as a distinct species (Turner et al., 2016) and is widely distributed across many regions, located in the following southern African countries: Botswana, Burundi, Eswatini, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Somalia, Tanzania, Uganda, Zambia, and Zimbabwe. In South Africa, they occur in all nine provinces of South Africa (Fig. 1.1); and are dependent on water sources and trees for food and cover while exploiting a range of terrestrial habitats, including savanna grasslands, cultivated land, many types of woodland and the forest-grassland mosaic (Isbell, 2013; Butynski and De Jong, 2019).

1.3.2 Vervet monkey ecology

Vervet monkeys are medium-sized, semi-arboreal primates that have a greyish fur coat. Their faces, ears, hands and feet, and tail tips are black in colour. The species is sexually dimorphic, where males are significantly larger than females (Izar et al., 2021). Vervet monkeys live in

multi-male and multi-female troops ranging from 17 to 53 individuals (Skinner and Chimimba, 2005; Patterson et al., 2018). Vervet males and females are ranked according to their social hierarchy, which reflects the rank based on social interactions within troops that comprise an alpha male, dominant females based on maternal social status, subordinate males and females, juveniles, and infants (Isbell et al., 1991; Hector and Raleigh, 1992; Isbell et al., 2004). Male vervets emigrate from their natal troop while females remain (Cheney and Seyfarth, 1983). Vervet monkeys are seasonal breeders, and mating takes place from April to June and gives birth in the warmer and wetter months from September, when food is abundant (Baldellou and Adan, 1997). Vervet monkeys are primarily vegetarian, foraging on plant material but are also known to feed on birds' eggs, lizards, invertebrates, and other small vertebrates (Turner et al., 2016). The troops' daily behavioural activities of foraging, playing, grooming, and resting remain unaffected by their overall territory and home ranges (McGuire et al., 1994; Barrett et al., 2010; Pasternak et al., 2013; Patterson et al., 2018; Canteloup et al., 2021).

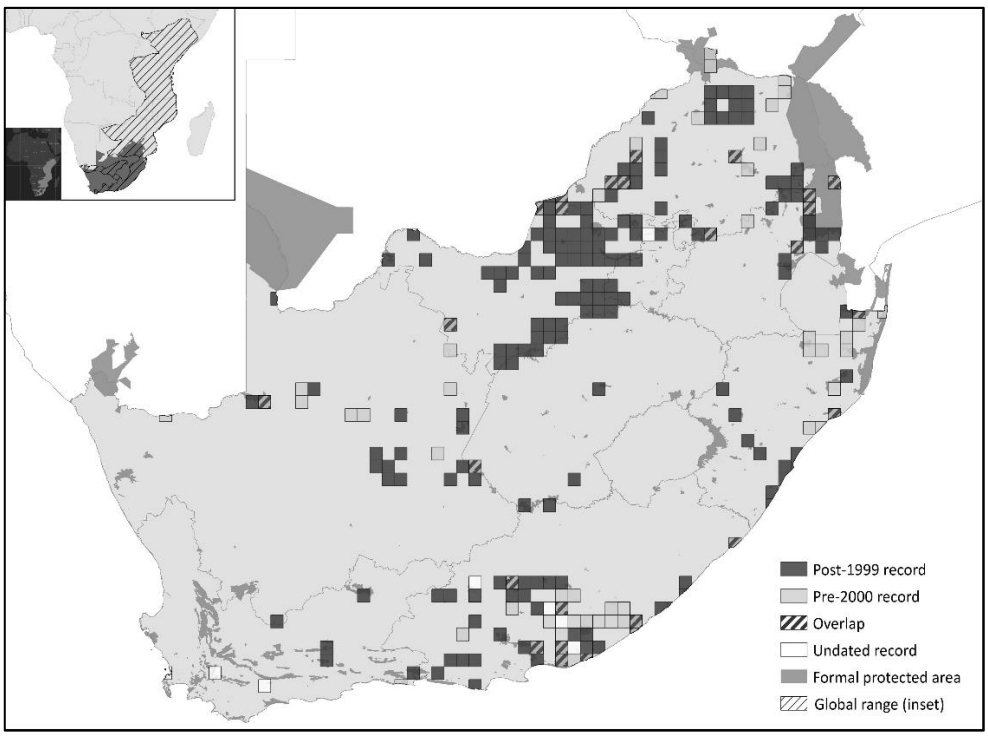


Fig. 1.1 Vervet monkey (*Chlorocebus pygerythrus*) distribution records in South Africa adapted from Turner et al. (2016) and Butynski and De Jong (2019).

1.3.3 Threats, conservation status and protection

Although there are no major threats to vervet monkeys, they have been classed as vermin and are often persecuted because of crop-raiding and close encounters with people, observed significantly in parts of the North-West and KwaZulu-Natal provinces (Wimberger and Downs, 2010; Healy and Nijman, 2014; Schmitt et al., 2020). Healy and Nijman (2014) reported multiple deaths of vervet monkeys by road traffic, infrastructure, and increasing urbanisation. In 2019, several local newspapers in KwaZulu-Natal reported on thirteen dead vervet monkeys poisoned by bread laced with insecticide (Supplementary information Fig. S1.1). The direct threats on vervet monkeys by humans in eThekwini Municipality are apparent but have not been documented in the scientific literature.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which regulates the trade of wildlife, lists vervet monkeys in Appendix II. No legislation warrants the protection and conservation of the vervet monkey as it is regarded a common species. Table 1.1 summarises the international and national legislation that endorses the lack of protection of vervet monkeys owing to repeated conflict events and acquiring the status of "problem" or "damage causing animal". In South Africa, the National Environmental Management: Biodiversity Act No. 10 of 2004 provides for the management and conservation of all biodiversity and the protection of all species and ecosystems, which warrant protection within the framework of the National Environmental Management Act, 1998. However, each of the nine provinces has its specific legislation that regulates the protection of wildlife and, in this case, vervet monkeys. It must be noted that in some provinces, the ordinances pre-date a democratic country and apply to the former homelands, considering the impacts of vervet monkeys in the past, which do not apply to the present-day context (Hamer et al., 2021). Additionally, the status of vervet monkeys differs from province to province leading to further

confusion and challenges in the decision-making processes for the management of this conflict species, intensifying the problems faced by human-vervet conflict in the country.

Table 1.1 Conservation legislation and status of the vervet monkey, *Chlorocebus pygerythrus*, in South Africa and Africa.

Legislation	**Status**	**Reference/Province**
CITES listing	Appendix II	CITES (2021)
IUCN Red List of Threatened Species	Least Concern	Butynski and de Jong (2019)
The Red List of Mammals of South Africa, Swaziland and Lesotho	Least Concern	Turner et al. (2016)
National Environmental. Management: Biodiversity Act, 2004 (Act 10 of 2004): Threatened or Protected Species (TOPS) Regulations	None	NEMBA: TOPS (2004)
Ciskei Nature Conservation Act 10 of 1987: - Chapter 2: Wild Animals - 7-18	Schedule 3: Huntable wild animals	Eastern Cape
Nature Conservation Ordinance 8 Of 1969	None	Free State
Natal Nature Conservation Ordinance 15 of 1974: - Chapter V: Mammals - 80 (1) (a) and (b) no permits granted for the keeping of any indigenous monkey unless for research institution, museum, or circus, or registered zoo	None	KwaZulu-Natal
Nature Conservation Ordinance 12 of 1983	None	Gauteng
Limpopo Environmental Management Act 7 of 2003: - "game" means any living or dead wild animal referred to in Schedule 4; and can be hunted, caught, kept with a legitimate permit	Schedule 4: Game Mammals	Limpopo
Mpumalanga Nature Conservation Act 10 of 1998: - Section 33 Prohibited Acts with certain live wild animals	Schedule 5: Wild Animals to which the provisions of Section 33 apply	Mpumalanga
Northern Cape Nature Conservation Act 9 of 2009: - Chapter 4: Damage Causing Animals - 28-30	Schedule 4: Damage Causing Animal Species	Northern Cape
Transvaal Nature Conservation Ordinance No. 12 Of 1983: - Chapter V: Problem Animals - 56. (1) The wild animals referred to in Schedule 8 to this Ordinance shall be problem animals and are deemed to be vermin or other animals causing damage.	Schedule 8: Problem Animals (Section 56)	North-West
Cape Nature and Environmental Conservation Ordinance 19 of 1974	None	Western Cape

1.4 eThekwini Municipality

The eThekwini Municipality is located on the east coast of South Africa in the Province of KwaZulu-Natal (KZN) and was created in 2000. It spans an area of approximately 2 555 km^2 and includes the city of Durban, as its central business district, with Tongaat in the north, Umkomaas in the south and Cato Ridge to the west (COGTA, 2020). It consists of a diverse society that faces various social, economic, environmental and governance challenges. In 2001, the population of eThekwini Municipality was 3.09 million and grew at an average annual rate of 1.1% per annum to reach 3.44 million in 2011 (StatsSA, 2011). Currently, the population is 3.9 million people, accounting for 34.7% of the total population of the KZN Province (COGTA, 2020). The eThekwini Municipality serves 110 wards, 68% of which are peri-urban or rural and historically under development (Shezi and Ngcoya, 2016).

The settlement type of the eThekwini Municipality is divided with the largest area constituting 84.8% being urban, tribal/traditional area (14.7%) and the smallest area (0.5%) belonging to farms (StatsSA, 2011). Although farmland is the smallest settlement type in the municipality, there are about 105 567 agricultural households, compared to the municipality's 956 713 households (StatsSA, 2011). Agricultural households in the eThekwini Municipality engage in farming activities which include livestock, poultry, vegetable, sugar cane, other crops, and other agricultural activities (StatsSA, 2011). Although agricultural land is restricted, recently, there has been an increase in urban agriculture because of the phenomenon of urbanisation in post-Apartheid South Africa (Shezi and Ngcoya, 2016). Furthermore, migration of people from rural areas or other parts of South Africa and the world adds to high rates of urbanisation and a growing urban population within the municipality, with core areas of the CBD being the most populated (IDP, 2021). Migration has implications for the labour force, social services, infrastructure, housing, and basic household services backlogs. The

municipality faces challenges that need to address social and developmental issues, such as acquiring more land for housing and basic services, which are greatly accelerated because of the growing population along the urban periphery (IDP, 2021). These societal issues are important for the city's land-use planning and biodiversity management in response to human-wildlife conflict.

The eThekwini Municipality is endowed in terms of natural capital since it is within a Biodiversity Hotspot called the Maputaland-Pondoland-Albany Region (Sutherland et al., 2018). Although the city is primarily urban, residential, and industrial areas are interspersed between large green spaces (94 834 ha) identified as part of the Durban Metropolitan Open Space System (D'MOSS) (Bux et al., 2021). D'MOSS land presents a mosaic landscape containing several ecosystems that include wetlands, woodlands, forests, grasslands, and beaches in private and public spaces, which includes a range of wildlife species (EPCPD, 2020; Zungu et al., 2020a). Despite the city's efforts to contain biodiversity and ecosystems, there is still habitat loss because of human activities (EPCPD, 2020). Some of the major threats to the eThekwini's terrestrial biodiversity and ecosystems are the transformation of the natural environment caused by habitat destruction, fragmentation and degradation, invasive alien species, over-exploitation, pollution, diseases, and climate change (EPCPD, 2020). Such anthropogenic disturbances are known to alter patterns of behaviour of wildlife living in cities and can cause declines (Lowry et al., 2013). Alternatively, some species can adapt and flourish under stressful conditions and survive by exploiting novel resources effectively in urban suburbia (McKinney, 2006; Tuomainen and Candolin, 2011). Certain primate species are intelligent, opportunistic and can easily adjust to anthropogenic environments (Nowak and Lee, 2013), but this may lead to acquiring the status of 'pest' species in suburbia, similarly observed in vervet monkeys (Hill and Webber, 2010).

The basic survival of wildlife requires movement in search of food, water, habitat space and nesting sites (Yarrow, 2009). As vervet monkeys live near urban settlements of the eThekwini Municipality, the potential for problematic interactions arises, leading to human-wildlife conflict since humans and wildlife inhabit a shared landscape. Wildlife that seeks refuge close to human-modified areas live relatively close to humans, eat leftover pet food or rummage through the waste refuse, and may cause damage to residential property, all of which are not welcomed by people in suburbia (Neumann et al., 2013). Frustrated residents may react negatively to the presence of vervet monkeys and use extreme deterrent methods such as shooting or poisoning to eradicate these nuisance events from reoccurring (Else, 1991; Ogada, 2014). Vervet monkeys can exploit human-altered environments well, leading to human-vervet conflict through a range of anthropogenic risks (Wimberger and Downs, 2010). Although citizen science data revealed that 67% of respondents appreciated vervet monkeys in suburban gardens, 29% disliked vervet monkeys "due to their aggressiveness, destructive behaviour" (Patterson et al., 2017). This study will document the interactions, including conflicts, and highlight the threats of anthropogenic activity on vervet monkeys in the urban mosaic landscape.

1.5 Problem statement and significance of the study

The vervet monkey is one non-human primate species that is persisting in the human-modified landscape, particularly in the urban forest mosaic landscape of KwaZulu-Natal Province, South Africa. The high presence of troops of vervet monkeys within the metropolitan city of eThekwini Municipality provides an opportunity to investigate aspects of urban ecology, spatial ecology, and human-wildlife conflicts. Increased human population growth and associated urban transformation have increased contact between humans and vervet monkeys that make use of residential and industrial gardens. This has led to increased human-wildlife

interactions, with vervet monkeys often persecuted because of their damage caused to human property and harassment leading to human-wildlife conflict. The impact of urbanisation on vervet monkeys (particularly in eThekwini and Msunduzi Municipalities) was poorly understood prior to recent research (Patterson et al., 2016; Patterson et al., 2017; Patterson et al., 2018) that contributed to new knowledge of vervet monkeys. Still, little is known about the ecology of urban vervet monkeys living along the urban-forest mosaic. To assess and manage conflict associated with the species, there is a need to determine the aspects of the behavioural ecology of vervet monkey populations, particularly in the urban environment. Urban sprawl has significantly increased human interactions with individuals and troops of vervets, resulting in increased conflict, especially in KwaZulu-Natal (Wimberger and Downs, 2010; Healy and Nijman, 2014). Furthermore, scientific research on vervet monkeys will provide a better understanding of troop behaviour, mortality and morbidity, diet, competition, and its spatial ecology within an urban mosaic landscape. All aspects of the present project were constructed with the goal of contributing to the management of the vervet monkey troops. By focusing on urban vervet monkey populations in the eThekwini Municipality, within the KwaZulu-Natal province, this study can provide an indication of the status of populations, thereby providing insights that will allow for adequate management practices and challenge procedures of the existing policies and legislation for vervet monkey protection and conservation.

1.6 Aims and objectives

The overall aim of the study was to investigate the need to determine the behavioural ecology and persistence of vervet monkeys in mosaic urban landscapes of KwaZulu-Natal. In addition, the impacts of anthropogenic activities with implications for the management recommendations of the species are presented. This study had the following objectives:

- To determine the home range, core area utilisation, and habitat use of vervet monkeys in an urban forest mosaic landscape of KwaZulu-Natal (Chapter 2).
- To determine human-wildlife conflicts experienced between vervet monkeys and people by using admission data from a wildlife rehabilitation centre in the eThekwini Municipality (Chapter 3).
- To determine the cause of pregnancy complications documented in wild female vervet monkeys using admission data from a wildlife rehabilitation centre in the eThekwini Municipality (Chapter 4).
- To assess and quantify the media's response to reporting on vervet monkeys in South Africa (Chapter 5).
- To provide management recommendations for the conservation of vervet monkeys impacted by anthropogenic activities in urban mosaic landscapes in KwaZulu-Natal.

1.7 Thesis arrangement

The thesis consists of six chapters, of which four are prepared as manuscripts for submission and publication in relevant international peer-reviewed journals. This thesis is structured with an introduction that provides the literature review of the concepts and rationale covered in this study. The following chapters: Chapters 2, 3, 4 and 5 are experimental chapters, each covering a specific objective and formatted according to the journal it is intended to be (or has been) submitted to. Thus, some repetitions in the chapters were unavoidable, especially in the respective method section. The hypotheses and predictions are presented in the respective chapters. The chapters are outlined as follows:

Chapter 1: Introduction

Chapter 2: Home range and habitat use of vervet monkeys in the urban forest mosaic landscape of Durban, eThekwini Municipality, KwaZulu-Natal, South Africa

Chapter 3: Surviving the urban jungle - vervet monkeys facing human-wildlife conflict in South Africa

Chapter 4: Pregnancy complications in wild vervet monkeys in the urban mosaic landscape

Chapter 5: Media framing of vervet monkeys: implications for human-wildlife interactions in South Africa

Chapter 6: Conclusions. The concluding chapter summarizes the various components of this study and provides recommendations.

1.8 References

Alemayehu, N., and W. Tekalign. 2020. Prevalence of crop damage and crop-raiding animals in southern Ethiopia: The resolution of the conflict with the farmers. *GeoJournal*:1-15.

Anand, S., V.V. Binoy, and S. Radhakrishna. 2018. The monkey is not always a God: Attitudinal differences toward crop-raiding macaques and why it matters for conflict mitigation. *Ambio*, 47:711-720.

Anand, S., and S. Radhakrishna. 2017. Investigating trends in human-wildlife conflict: is conflict escalation real or imagined? *Journal of Asia-Pacific Biodiversity*, 10:154-161.

Arroyo-Rodríguez, V., and S. Mandujano. 2009. Conceptualization and measurement of habitat fragmentation from the primates' perspective. *International Journal of Primatology*, 30:497-514.

Arroyo-Rodríguez, V., E.C. Moral, S. Mandujano, C.A. Chapman, R. Reyna-Hurtado, and L. Fahrig. 2013. Assessing habitat fragmentation effects on primates: the importance of evaluating questions at the correct scale. In: Marsh, L., & Chapman, C. (Eds), *Primates in Fragments. Developments in Primatology: Progress and Prospects.* Springer, New York, NY, pp. 13-28. https://doi.org/10.1007/978-1-4614-8839-2_2

Arroyo-Rodríguez, V., G.K. Pérez-Elissetche, J.D. Ordóñez-Gómez, A. González-Zamora, Ó.M. Chaves, S. Sánchez-López, C.A. Chapman, K. Morales-Hernández, M. Pablo-Rodríguez, and G. Ramos-Fernández. 2017. Spider monkeys in human-modified landscapes: the importance of the matrix. *Tropical Conservation Science*, 10:1-13.

Ascensão, F., M. D'Amico, and R. Barrientos. 2021. No planet for Apes? Assessing global priority areas and species affected by linear infrastructures. *International Journal of Primatology,* 43:57–73. https://doi.org/10.1007/s10764-021-00207-5

Baldellou, M., and A. Adan. 1997. Time, gender, and seasonality in vervet activity: a chronobiological approach. *Primates*, 38:31-43.

Banks, S.C., M.P. Piggott, A.J. Stow, and A.C. Taylor. 2007. Sex and sociality in a disconnected world: a review of the impacts of habitat fragmentation on animal social interactions. *Canadian Journal of Zoology*, 85:1065-1079.

Barrett, A.S., L.R. Brown, L. Barrett, and P. Henzi. 2010. A floristic description and utilisation of two home ranges by vervet monkeys in Loskop Dam Nature Reserve, South Africa. *Koedoe: African Protected Area Conservation and Science*, 52:1-12.

Barua, M., S.A. Bhagwat, and S. Jadhav. 2013. The hidden dimensions of human-wildlife conflict: health impacts, opportunity and transaction costs. *Biological Conservation*, 157:309-316.

Basckin, D.R., and P.D. Krige. 1973. Some preliminary observations on the behaviour of an urban troop of vervet monkeys (*Cercopithecus aethiops*) during the birth season. *Journal of Behavioural Science*, 1:287-296.

Bloomfield, L.S.P., T.L. McIntosh, and E.F. Lambin. 2020. Habitat fragmentation, livelihood behaviors, and contact between people and nonhuman primates in Africa. *Landscape Ecology*, 35:985-1000.

Boal, C.W., and C.R. Dykstra. 2018. Urban raptors: ecology and conservation of birds of prey in cities. Island Press, Washington DC.

Bombieri, G., M.d.M. Delgado, L.F. Russo, P.J. Garrote, J.V. López-Bao, J.M. Fedriani, and V. Penteriani. 2018. Patterns of wild carnivore attacks on humans in urban areas. *Scientific Reports*, 8:1-9.

Borah, D.K., G.S. Solanki, and P.C. Bhattacharjee. 2021. Feeding ecology of capped langur (*Trachypithecus pileatus*) in Sri Surya Pahar, a disturbed habitat in Goalpara District, Assam, India. *Tropical Ecology*, 62:492-498.

Brennan, E.J., J.G. Else, and J. Altmann. 1985. Ecology and behaviour of a pest primate: vervet monkeys in a tourist-lodge habitat. *African Journal of Ecology*, 23:35-44.

Bruskotter, J.T., J.A. Vucetich, M.J. Manfredo, G.R. Karns, C. Wolf, K. Ard, N.H. Carter, J.V. López-Bao, G. Chapron, and S.D. Gehrt. 2017. Modernization, risk, and conservation of the world's largest carnivores. *BioScience*, 67:646-655.

Butynski, T.M., and Y.A. De Jong. 2019. *Chlorocebus pygerythrus*. *The IUCN Red List of Threatened Species*:1-9.

Bux, Q., P. Anderson, and P. O'Farrell. 2021. Understanding the local biodiversity and open space strategies in two South African cities. *Ecology and Society*, 26:1-4.

Cancelliere, E.C., C.A. Chapman, D. Twinomugisha, and J.M. Rothman. 2018. The nutritional value of feeding on crops: Diets of vervet monkeys in a humanized landscape. *African Journal of Ecology*, 56:160-167.

Canteloup, C., I. Puga-Gonzalez, C. Sueur, and E. van de Waal. 2021. The consistency of individual centrality across time and networks in wild vervet monkeys. *American Journal of Primatology*, 83:1-13.

Chapman, C.A., and J.F. Gogarten. 2012. Primate Conservation: Is the Cup Half Empty or Half Full? *Nature Education Knowledge*, 4:1-7.

Chapman, C.A., M.L. Speirs, T.R. Gillespie, T. Holland, and K.M. Austad. 2006. Life on the edge: gastrointestinal parasites from the forest edge and interior primate groups. *American Journal of Primatology*, 68:397-409.

Chapman, C.A., D. Twinomugisha, J.A. Teichroeb, K. Valenta, R. Sengupta, D. Sarkar, and J.M. Rothman. 2016. How do primates survive among humans? Mechanisms employed by vervet monkeys at Lake Nabugabo, Uganda. *In:* Ethnoprimatology. Springer. pp. 77-94.

Charles, K.E., and W.L. Linklater. 2013. Dietary breadth as a predictor of potential native avian-human conflict in urban landscapes. *Wildlife Research*, 40:482-489.

Cheney, D.L., and R.M. Seyfarth. 1983. Nonrandom dispersal in free-ranging vervet monkeys: social and genetic consequences. *American Naturalist*, 122:392-412.

COGTA. 2020. eThekwini Metropolitan, KZN. *In* Metro Profile Ethekwini.

Corrêa, F.M., Ó.M. Chaves, R.C. Printes, and H.P. Romanowski. 2018. Surviving in the urban-rural interface: Feeding and ranging behavior of brown howlers (*Alouatta guariba clamitans*) in an urban fragment in southern Brazil. *American Journal of Primatology*, 80:1-39.

Crist, E., C. Mora, and R. Engelman. 2017. The interaction of human population, food production, and biodiversity protection. *Science*, 356:260-264.
de Almeida-Rocha, J.M., C.A. Peres, and L.C. Oliveira. 2017. Primate responses to anthropogenic habitat disturbance: a pantropical meta-analysis. *Biological Conservation*, 215:30-38.
Dickman, A.J. 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation*, 13:458-466.
Distefano, E. 2005. Human-Wildlife Conflict worldwide: collection of case studies, analysis of management strategies and good practices. *Food and Agricultural Organization of the United Nations* 1-34.
Elliot, E.E., S. Vallance, and L.E. Molles. 2016. Coexisting with coyotes (Canis latrans) in an urban environment. *Urban Ecosystems*, 19:1335-1350.
Else, J.G. 1991. Nonhuman primates as pests. *In* Primate responses to environmental change. Springer. pp. 155-165.
EPCPD. 2020. Durban: State of Biodiversity Report 2019/2020. © eThekwini Municipality, 2020.
Estrada, A., P.A. Garber, A.B. Rylands, C. Roos, E. Fernandez-Duque, A. Di Fiore, K.A.-I. Nekaris, V. Nijman, E.W. Heymann, and J.E. Lambert. 2017. Impending extinction crisis of the world's primates: Why primates matter. *Science Advances*, 3:1-17.
Estrada, A., B.E. Raboy, and L.C. Oliveira. 2012. Agroecosystems and primate conservation in the tropics: a review. *American Journal of Primatology*, 74:696-711.
Ewers, R.M., and R.K. Didham. 2006. Confounding factors in the detection of species responses to habitat fragmentation. *Biological Reviews*, 81:117-142.
Fedigan, L.M. 2010. Ethical issues faced by field primatologists: Asking the relevant questions. *American Journal of Primatology*, 72:754-771.
Fehlmann, G., M.J. O'Riain, I. FÜrtbauer, and A.J. King. 2021. Behavioral causes, ecological consequences, and management challenges associated with wildlife foraging in human-modified landscapes. *BioScience*, 71:40-54.
Forss, S.I.F., A. Motes-Rodrigo, P. Dongre, T. Mohr, and E. van de Waal. 2021. Captivity and habituation to humans raise curiosity in vervet monkeys. *Animal cognition*:1-12.
Fuentes, A. 2012. Ethnoprimatology and the anthropology of the human-primate interface. *Annual Review of Anthropology*, 41:101-117.
Galán-Acedo, C., V. Arroyo-Rodríguez, E. Andresen, L. Verde Arregoitia, E. Vega, C.A. Peres, and R.M. Ewers. 2019. The conservation value of human-modified landscapes for the world's primates. *Nature Communications*, 10:1-8.
Galán-Acedo, C., V. Arroyo-Rodríguez, S.J. Cudney-Valenzuela, and L. Fahrig. 2019. A global assessment of primate responses to landscape structure. *Biological Reviews*, 94:1605-1618.
Gayen, D., S. Dey, A.K. Dey, and U.S. Roy. 2019. Fate of snakes in an urban landscape - A report from Durgapur, Paschim Bardhaman, West Bengal, India. *Zoo's Print,* 34:12-19.
Grimm, N.B., J.G. Grove, S.T.A. Pickett, and C.L. Redman. 2000. Integrated approaches to long-term studies of urban ecological systems: Urban ecological systems present multiple challenges to ecologists - Pervasive human impact and extreme heterogeneity of cities, and the need to integrate social and ecological approaches, concepts, and theory. *BioScience*, 50:571-584.
Gross, E., N. Jayasinghe, A. Brooks, G. Polet, R. Wadhwa, and F. Hilderink-Koopmans. 2021. A Future for All: The Need for Human-Wildlife Coexistence, WWF, Gland, Switzerland. 1-102.

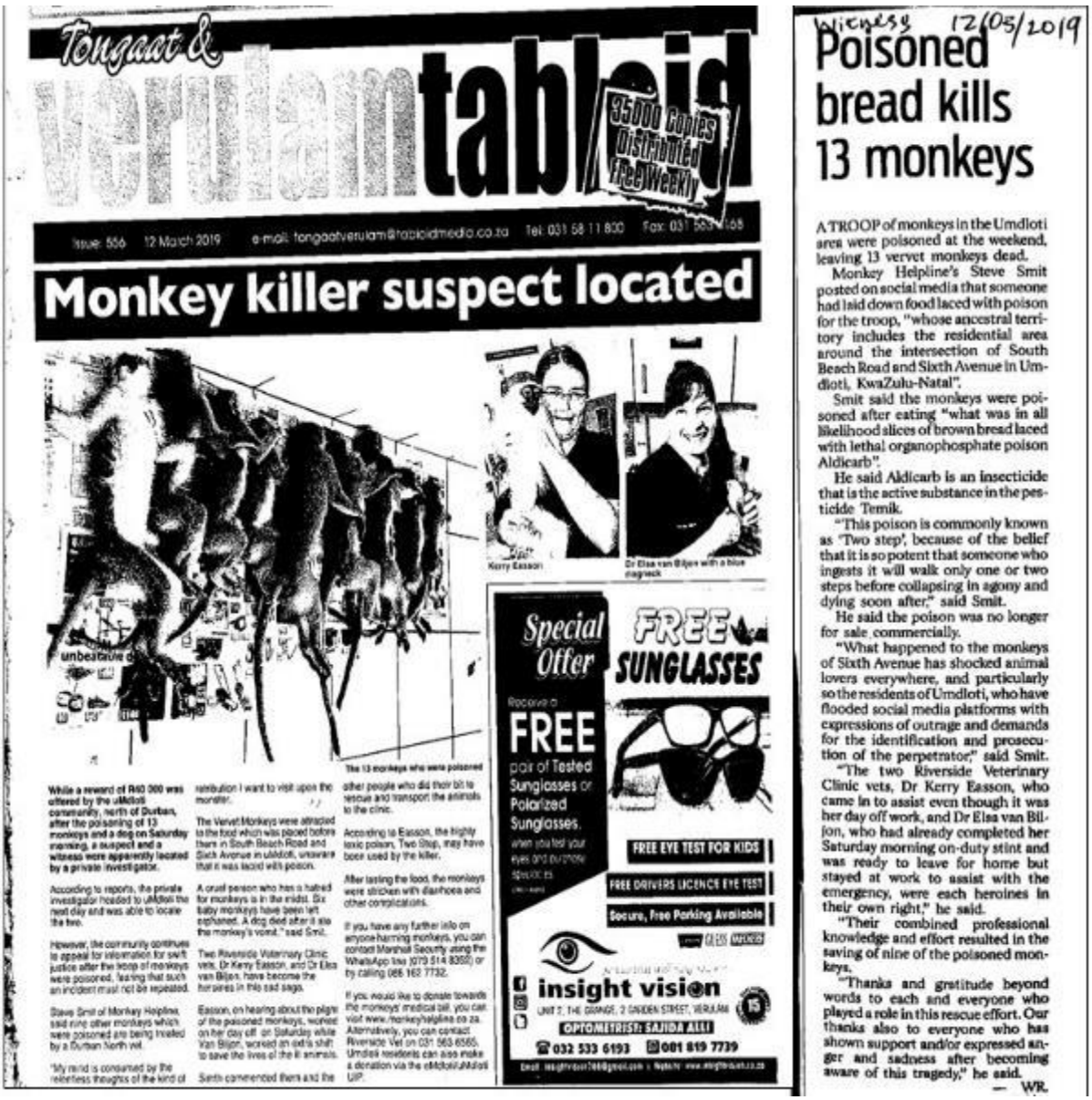
Hamer, M., K. Behr, I. Engelbrecht, and L. Richards. 2021. Permit requirements, associated challenges and recommendations for biodiversity collections and research in South Africa. *South African Journal of Science*, 117:1-4.
Healy, A., and V. Nijman. 2014. Pets and pests: vervet monkey intake at a specialist South African rehabilitation centre. *Animal Welfare*, 23:353-360.
Hector, A.K., and M.J. Raleigh. 1992. The effects of temporary removal of the alpha male on the behavior of subordinate male vervet monkeys. *American Journal of Primatology*, 26:77-87.
Hill, C.M. 1997. Crop-raiding by wild vertebrates: The farmer's perspective in an agricultural community in western Uganda. *International Journal of Pest Management*, 43:77-84.
Hill, C.M. 2002. Primate conservation and local communities - ethical issues and debates. *American Anthropologist*. 104:1184-1194.
Hill, C.M., and A.D. Webber. 2010. Perceptions of nonhuman primates in human–wildlife conflict scenarios. *American Journal of Primatology*, 72:919-924.
Hill, C.M., 2018. Crop foraging, crop losses, and crop raiding. *Annual Review of Anthropology*, 47:377-394.
Hockings, K.J. 2016. Mitigating Human-Nonhuman Primate Conflict. In: K.C.M. M. Bezanson, E. Riley, C.J. Campbell, K. Nekaris, A. Estrada, A.F. Di Fiore, S. Ross, L.E. Jones-Engel, B. Thierry, R.W. Sussman, C. Sanz, J. Loudon, S. Elton and A. Fuentes, (Eds.) The International Encyclopedia of Primatology. 1-2.
Hockings, K.J., M.R. McLennan, S. Carvalho, M. Ancrenaz, R. Bobe, R.W. Byrne, R.I.M. Dunbar, T. Matsuzawa, W.C. McGrew, and E.A. Williamson. 2015. Apes in the Anthropocene: flexibility and survival. *Trends in Ecology & Evolution*, 30:215-222.
Hoffman, T.S., and M.J. O'Riain. 2012. Landscape requirements of a primate population in a human-dominated environment. *Frontiers in Zoology*, 9:1-17.
IDP, E. 2021. Integrated Development Plan (IDP) 2020/2021.
Ingle, M., U. Yadav, A.K. Bhilala, and M. Pawar. 2019. Urban herpetofauna: A case study in Ujjain City of central India. *International Journal of Scientific Research in Biological Sciences,* 6:76-84.
Isbell, L.A., D.L. Cheney, and R.M. Seyfarth. 1991. Group fusions and minimum group sizes in vervet monkeys (*Cercopithecus aethiops*). *American Journal of Primatology*, 25:57-65.
Isbell, L.A., D.L. Cheney, and R.M. Seyfarth. 2004. Why vervet monkeys (*Cercopithecus aethiops*) live in multimale groups. *In* The guenons: Diversity and adaptation in African monkeys. Springer. pp. 173-187.
Isbell, L.A., and T.P. Young. 1993. Human presence reduces predation in a free-ranging vervet monkey population in Kenya. *Animal Behaviour*, 45:1233-1235.
Isbell, L.A.a.J., K.E. 2013. *Chlorocebus pygerythrus* Vervet Monkey. In: K. Butynski T.M., J. and Kalina, J. (Eds). The Mammals of Africa. Volume II: Primates. Bloomsbury Publishing, London. pp. 277-283.
Izar, P., M. Fernández-Bolaños, L. Seex, G. Gort, P. Suscke, M. Tokuda, O. Mendonça-Furtado, M.P. Verderane, and C.K. Hemelrijk. 2021. Female emancipation in a male dominant, sexually dimorphic primate under natural conditions. *PloS One*, 16:1-16.
Kalbitzer, U., and C.A. Chapman. 2018. Primate responses to changing environments in the Anthropocene. In: Primate life histories, sex roles, and adaptability. Springer. pp. 283-310.
Kumar, N., Y.V. Jhala, Q. Qureshi, A.G. Gosler, and F. Sergio. 2019. Human-attacks by an urban raptor are tied to human subsidies and religious practices. *Scientific Reports*, 9:1-10.

LaBarge, L.R., R.A. Hill, C.M. Berman, S.W. Margulis, and A.T.L. Allan. 2020. Anthropogenic influences on primate antipredator behavior and implications for research and conservation. *American Journal of Primatology*, 82:1-42.
Lowry, H., A. Lill, and B.B.M. Wong. 2013. Behavioural responses of wildlife to urban environments. *Biological Rreviews*, 88:537-549.
Manral, U., S. Sengupta, S.A. Hussain, S. Rana, and R. Badola. 2016. Human wildlife conflict in India: A review of economic implication of loss and preventive measures. *Indian Forester*, 142:928-940.
McGuire, M.T., M.J. Raleigh, and D.B. Pollack. 1994. Personality features in vervet monkeys: The effects of sex, age, social status, and group composition. *American Journal of Primatology*, 33:1-13.
McKinney, M.L. 2006. Urbanization as a major cause of biotic homogenization. *Biological Conservation*, 127:247-260.
McLennan, M.R., N. Spagnoletti, and K.J. Hockings. 2017. The implications of primate behavioral flexibility for sustainable human-primate coexistence in anthropogenic habitats. *International Journal of Primatology*, 38:105-121.
Meijaard, E., D. Buchori, Y. Hadiprakarsa, S.S. Utami-Atmoko, A. Nurcahyo, A. Tjiu, D. Prasetyo, Nardiyono, L. Christie, M. Ancrenaz, F. Abadi, I.N.G. Antoni, D. Armayadi, A. Dinato, Ella, P. Gumelar, T.P. Indrawan, Kussaritano, C. Munajat, C.W.P. Priyono, Y. Purwanto, D. Puspitasari, M.S.W. Putra, A. Rahmat, H. Ramadani, J. Sammy, D. Siswanto, M. Syamsuri, N. Andayani, H. Wu, J.A. Wells, and K. Mengersen. 2011. Quantifying killing of orangutans and human-orangutan conflict in Kalimantan, Indonesia. *PLoS One*, 6:1-10.
Mittermeier, R.A., J. Wallis, A.B. Rylands, J.U. Ganzhorn, J.F. Oates, E.A. Williamson, E. Palacios, E.W. Heymann, M.C.M. Kierulff, L. Yongcheng, J. Supriatna, C. Roos, S. Walker, L. Cortés-Ortiz, and C. Schwitzer. 2009. Primates in Peril: The World's 25 Most Endangered Primates 2008-2010. *Primate Conservation*, 24:1-57.
Moss, W.E., M.W. Alldredge, and J.N. Pauli. 2016. Quantifying risk and resource use for a large carnivore in an expanding urban-wildland interface. *Journal of Applied Ecology*, 53:371-378.
Murray, M., A. Cembrowski, A.D.M. Latham, V.M. Lukasik, S. Pruss, and C.C. St Clair. 2015. Greater consumption of protein-poor anthropogenic food by urban relative to rural coyotes increases diet breadth and potential for human-wildlife conflict. *Ecography*, 38:1235-1242.
Naughton-Treves, L., A. Treves, C. Chapman, and R. Wrangham. 1998. Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacent forest. *Journal of Applied Ecology*, 35:596-606.
Neumann, W., G. Ericsson, H. Dettki, and V.C. Radeloff. 2013. Behavioural response to infrastructure of wildlife adapted to natural disturbances. *Landscape and Urban Planning*, 114:9-27.
Nowak, K., and P.C. Lee. 2013. “Specialist” primates can be flexible in response to habitat alteration. In: Primates in Fragments. Springer. pp. 199-211.
Nunes, V.F., P.M. Lopes, and R.G. Ferreira. 2021. Monkeying around Anthropocene: Patterns of human-nonhuman primates’ interactions in Brazil. *Ethnobiology and Conservation* 10:1-32.
Nyhus, P. 2016. Human-Wildlife Conflict and Coexistence. *Annual Review of Environment and Resources* 41:143-171.
Ogada, D.L. 2014. The power of poison: pesticide poisoning of Africa's wildlife. *Annals of the New York Academy of Sciences*, 1322:1-20.

Parker, E.J., N.F. Koyama, and R.A. Hill. 2021. Habitat selection of an endangered primate, the samango monkey (*Cercopithecus albogularis schwarzi*): Integrating scales to prioritize habitat for wildlife management. *Ecology and Evolution*, 11:8014-8026.
Pasternak, G., S. Kienzle, L. Barrett, P. Henzi, L.R. Brown, and A. Fuller. 2013. Population ecology of vervet monkeys in a high latitude, semi-arid riparian woodland. *Koedoe: African Protected Area Conservation and Science*, 55:1-9.
Patterson, L., R. Kalle, and C. Downs. 2016. Predation of artificial bird nests in suburban gardens of KwaZulu-Natal, South Africa. *Urban Ecosystems*, 19:615-630.
Patterson, L., R. Kalle, and C. Downs. 2017. A citizen science survey: perceptions and attitudes of urban residents towards vervet monkeys. *Urban Ecosystems*, 20:617-628.
Patterson, L., R. Kalle, and C. Downs. 2018. Factors affecting presence of vervet monkey troops in a suburban matrix in KwaZulu-Natal, South Africa. *Landscape and Urban Planning*, 169:220-228.
Peterson, M.N., J.L. Birckhead, K. Leong, M.J. Peterson, and T.R. Peterson. 2010. Rearticulating the myth of human-wildlife conflict. *Conservation Letters*, 3:74-82.
Priston, N.E.C., R.M. Wyper, and P.C. Lee. 2012. Buton macaques (*Macaca ochreata brunnescens*): crops, conflict, and behavior on farms. *American Journal of Primatology*, 74:29-36.
Riley, E.P. 2007. Flexibility in diet and activity patterns of *Macaca tonkeana* in response to anthropogenic habitat alteration. *International Journal of Primatology*, 28:107-133.
Rodrigues, N.N., and R.A. Martinez. 2014. Wildlife in our backyard: interactions between Wied's marmoset *Callithrix kuhlii* (Primates: Callithrichidae) and residents of Ilhéus, Bahia, Brazil. *Wildlife Biology*, 20:91-96.
Saj, T.L., P. Sicotte, and J.D. Paterson. 2001. The conflict between vervet monkeys and farmers at the forest edge in Entebbe, Uganda. *African Journal of Ecology*, 39:195-199.
Santini, L., M. González-Suárez, D. Russo, A. Gonzalez-Voyer, A. von Hardenberg, and L. Ancillotto. 2019. One strategy does not fit all: determinants of urban adaptation in mammals. *Ecology Letters*, 22:365-376.
Satterthwaite, D., G. McGranahan, and C. Tacoli. 2010. Urbanization and its implications for food and farming. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365:2809-2820.
Schell, C.J., L.A. Stanton, J.K. Young, L.M. Angeloni, J.E. Lambert, S.W. Breck, and M.H. Murray. 2021. The evolutionary consequences of human–wildlife conflict in cities. *Evolutionary Applications*, 14:178-197.
Schmitt, C.A., A.M. Rich, S.-A.R. Parke, M.B. Blaszczyk, J.D. Cramer, N.B. Freimer, J.P. Grobler, and T.R. Turner. 2020. Anthropogenic food enhancement alters the timing of maturational landmarks among wild savanna monkeys (*Chlorocebus pygerythrus*). *bioRxiv*:1-34.
Schwitzer, C., L. Glatt, K.A.-I. Nekaris, and J.U. Ganzhorn. 2011. Responses of animals to habitat alteration: an overview focussing on primates. *Endangered Species Research*. 14:31-38.
Shezi, N., and M. Ngcoya. 2016. Adaptation to the impacts of climate change on agriculture in eThekwini: a literature review. Vol. 7. University of KwaZulu-Natal. 1-34.
Sillero-Zubiri, C., and D. Switzer. 2001. Crop raiding primates: searching for alternative, humane ways to resolve conflict with farmers in Africa. Wildlife Conservation Research Unit, Oxford University, Oxford. pp.1-19.
Singh, R.L., and P.K. Singh. 2017. Global environmental problems. In: Principles and applications of environmental biotechnology for a sustainable future. Springer. pp.13-41.

Skinner, J.D., and C.T. Chimimba. 2005. The mammals of the southern African sub-region. Cambridge University Press, Cape Town.
Soulsbury, C.D., and P.C.L. White. 2015. Human-wildlife interactions in urban areas: a review of conflicts, benefits and opportunities. *Wildlife Research*, 42:541-553.
StatsSA. 2011. eThekwini Municipality
Storm, D.J., C.K. Nielsen, E.M. Schauber, and A. Woolf. 2007. Deer-human conflict and hunter access in an exurban landscape. *Human-Wildlife Conflicts*. 1:53-59.
Sutherland, C., D. Scott, E. Nel, and A. Nel. 2018. Conceptualizing 'the urban' through the lens of Durban, South Africa. *Urban Forum*, 29:333-350.
Swarna, N., and C. Tisdell. 2009. The orangutan-oil palm conflict: economic constraints and opportunities for conservation. *Biodiversity and Conservation*, 18:487-502.
Thatcher, H.R., C.T. Downs, and N.F. Koyama. 2019. Anthropogenic influences on the time budgets of urban vervet monkeys. *Landscape and Urban Planning*, 181:38-44.
Thatcher, H.R., C.T. Downs, and N.F. Koyama. 2020. Understanding foraging flexibility in urban vervet monkeys, *Chlorocebus pygerythrus*, for the benefit of human-wildlife coexistence. *Urban Ecosystems*, 23:1349-1357.
Thirgood, S., and R. Woodroffe. 2005. The impact of human-wildlife conflict on human. *People and wildlife, conflict or co-existence?* 9:1-13.
Treves, A., and K.U. Karanth. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. *Conservation Biology*, 17:1491-1499.
Tuomainen, U., and U. Candolin. 2011. Behavioural responses to human-induced environmental change. *Biological Reviews*, 86:640-657.
Turner, T., R. Hill, W. Coetzer, and L. Patterson. 2016. A Conservation Assessment of *Chlorocebus pygerythrus*. *South Africa: South African National Biodiversity Institute and Endangered Wildlife Trust*:1-6.
Tweheyo, M., C.M. Hill, and J. Obua. 2005. Patterns of crop raiding by primates around the Budongo Forest Reserve, Uganda. *Wildlife Biology*, 11:237-247.
Uddin, M.M., M.F. Ahsan, and H. Lingfeng. 2020. Human-primates conflict in Bangladesh: a review. *Journal of Animal and Plant Sciences*, 30:1-8.
van Bommel, J.K., M. Badry, A.T. Ford, T. Golumbia, and A.C. Burton. 2020. Predicting human-carnivore conflict at the urban-wildland interface. *Global Ecology and Conservation*, 24:1-12.
van Doorn, A.C., and M.J. O'Riain. 2020. Nonlethal management of baboons on the urban edge of a large metropole. *American Journal of Primatology*, 82:1-8.
Van Helden, B.E., P.G. Close, and R. Steven. 2020. Mammal conservation in a changing world: can urban gardens play a role? *Urban Ecosystems*, 23:555-567.
Wallace, G.E., and C.M. Hill. 2012. Crop Damage by Primates: Quantifying the Key Parameters of Crop-Raiding Events. *PLOS One*, 7:1-13.
Wiafe, E.D. 2019. Primates crop raiding situation on farmlands adjacent to South-West of Mole National Park, Ghana. *Ghana Journal of Agricultural Science*, 54:58-67.
Wimberger, K., and C.T. Downs. 2010. Annual intake trends of a large urban animal rehabilitation centre in South Africa: a case study. *Animal Welfare*, 19:501-513.
Yarrow, G. 2009. Habitat requirements of wildlife: food, water, cover and space. *Forestry and Natural Resources*, 14:1-5.
Zungu, M.M., M.S.T. Maseko, R. Kalle, T. Ramesh, and C.T. Downs. 2020a. Effects of landscape context on mammal richness in the urban forest mosaic of EThekwini Municipality, Durban, South Africa. *Global Ecology and Conservation*, 21:126562.
Zungu, M.M., M.S.T. Maseko, R. Kalle, T. Ramesh, and C.T. Downs. 2020b. Factors affecting the occupancy of forest mammals in an urban-forest mosaic in EThekwini Municipality, Durban, South Africa. *Urban Forestry & Urban Greening*, 48:126562.

1.9 Supplementary information



Tongaat & Verulam tabloid

35000 Copies distributed FreeWeekly

Issue: 556 12 March 2019 e-mail: tongaatverulam@tabloidmedia.co.za Tel: 031 58 11 800 Fax: 031 563 4168

Monkey killer suspect located

While a reward of R40 000 was offered by the uMdloti community, north of Durban, after the poisoning of 13 monkeys and a dog on Saturday morning, a suspect and a witness were apparently located by a private investigator.

According to reports, the private investigator headed to uMdloti the next day and was able to locate the two.

However, the community continues to appeal for information for swift justice after the troop of monkeys were poisoned, fearing that such an incident must not be repeated.

Steve Smit of Monkey Helpline, said nine other monkeys which were poisoned are being treated by a Durban North vet.

"My mind is consumed by the relentless thoughts of the kind of retribution I want to visit upon the monster.

The Vervet Monkeys were attracted to the food which was placed before them in South Beach Road and Sixth Avenue in uMdloti, unaware that it was laced with poison.

A cruel person who has a hatred for monkeys is in the midst. Six baby monkeys have been left orphaned. A dog died after it ate the monkey's vomit," said Smit.

Two Riverside Veterinary Clinic vets, Dr Kerry Easson, and Dr Elsa van Biljon, have become the heroines in this sad saga.

Easson, on hearing about the plight of the poisoned monkeys, worked on her day off on Saturday while Van Biljon, worked an extra shift to save the lives of the ill animals.

Smit commended them and the other people who did their bit to rescue and transport the animals to the clinic.

According to Easson, the highly toxic poison, Two Step, may have been used by the killer.

After tasting the food, the monkeys were stricken with diarrhoea and other complications.

If you have any further info on anyone harming monkeys, you can contact Marshall Security using the WhatsApp line (079 514 8355) or by calling (66 162 7732.

If you would like to donate towards the monkeys' medical bill, you can visit www.monkeyhelpline.co.za. Alternatively, you can contact Riverside Vet on 031 563 6565. Umdloti residents can also make a donation via the #MdlotiUMdloti UIP.

Kerry Easson

Dr Elsa van Biljon with a blue magnack

The 13 monkeys who were poisoned

witness 12/05/2019

Poisoned bread kills 13 monkeys

A TROOP of monkeys in the Umdloti area were poisoned at the weekend, leaving 13 vervet monkeys dead.

Monkey Helpline's Steve Smit posted on social media that someone had laid down food laced with poison for the troop, "whose ancestral territory includes the residential area around the intersection of South Beach Road and Sixth Avenue in Umdloti, KwaZulu-Natal".

Smit said the monkeys were poisoned after eating "what was in all likelihood slices of brown bread laced with lethal organophosphate poison Aldicarb".

He said Aldicarb is an insecticide that is the active substance in the pesticide Temik.

"This poison is commonly known as 'Two step', because of the belief that it is so potent that someone who ingests it will walk only one or two steps before collapsing in agony and dying soon after," said Smit.

He said the poison was no longer for sale commercially.

"What happened to the monkeys of Sixth Avenue has shocked animal lovers everywhere, and particularly so the residents of Umdloti, who have flooded social media platforms with expressions of outrage and demands for the identification and prosecution of the perpetrator," said Smit.

"The two Riverside Veterinary Clinic vets, Dr Kerry Easson, who came in to assist even though it was her day off work, and Dr Elsa van Biljon, who had already completed her Saturday morning on-duty stint and was ready to leave for home but stayed at work to assist with the emergency, were each heroines in their own right," he said.

"Their combined professional knowledge and effort resulted in the saving of nine of the poisoned monkeys.

"Thanks and gratitude beyond words to each and everyone who played a role in this rescue effort. Our thanks also to everyone who has shown support and/or expressed anger and sadness after becoming aware of this tragedy," he said.

— WR.

Supplementary information Figure S1.1. Vervet monkey poisoning event reported in two different newspapers in KwaZulu-Natal, South Africa.

CHAPTER 2

Home range and habitat use of vervet monkeys in the urban forest mosaic landscape of Durban, eThekwini Municipality, KwaZulu-Natal, South Africa

Kerushka R. Pillay, Jarryd P. Streicher and Colleen T. Downs*

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

Formatted for Urban Ecosystems

*** Corresponding Author:** Colleen T. Downs

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

Other Emails and ORCIDs:

K. Pillay Email: kerushka@gmail.com; ORCID: https://orcid.org/0000-0002-4018-783X

J. Streicher Email: jarrydstreicher@gmail.com; ORCID: https://orcid.org/0000-0001-6229-820X

Running header: Urban home range and habitat use of vervet monkeys

2.1 Abstract

Generally, urbanisation affects biodiversity negatively; however, some species flourish in urban areas. One mammalian species persisting in the urban forest mosaic landscape is the vervet monkey (*Chlorocebus pygerythrus*), particularly in Durban, eThekwini Municipality, KwaZulu-Natal Province, South Africa. Vervet monkeys' spatial use can provide important ecological information to understand their behavioural plasticity in an urban forest mosaic landscape. We, therefore, captured, and collared vervet monkeys (n = 6) with Global Positioning System (GPS)-Ultra High Frequency (UHF) transmitters in two sites (Buffelsdraai Regional Landfill Site and the Bluff) of varying degrees of urban and natural land-use types within eThekwini Municipality. The three home range methods (Minimum Convex Polygon (MCP), Kernel Density Estimator (KDE), and Local Convex Hull (LoCoH) were used to determine individual home range size and core area use. The overall body mass was lower for male and female vervet monkeys compared with previous studies despite having relatively good body condition. Home range (47.27 ha 95% MCP) and core area (6.52 ha 50% KDE) estimates were relatively small for these vervet monkeys. Buffelsdraai vervet monkeys had a larger home range and troop size than the Bluff site. Forest and thicket, and built-up habitat types were most used by vervet monkeys across the urban forest mosaic landscape. Overall, individuals in this study showed that the vervet monkeys, regardless of the environment, can exist in the urban forest mosaic landscape successfully. The spatial ecology of urban vervet monkeys provides valuable information for future education and management interventions, especially where there are negative human-monkey interactions amongst urban communities.

Keywords: Chlorocebus pygerythrus, home range, habitat use, spatial ecology, telemetry.

2.2 Introduction

The expanding human population in municipalities is altering existing natural environments. More than half of the world's population lives in urban areas and could reach 2.5 billion by 2050 (UN DESA, 2019). Space is a primary concern as land is converted for anthropogenic infrastructure, housing developments and agriculture (Brueckner, 2000). Anthropogenic land-use change caused by urbanisation threatens biodiversity and transforms wildlife habitats (Zipperer et al., 2000; McKinney, 2006; Seto et al., 2013). Urban areas are becoming highly modified and complex landscapes that threaten wildlife as anthropogenic activities increase (Bar-Massada et al., 2014; Soulsbury and White, 2016). The detrimental effects caused within an anthropogenically transformed landscape have led to local extinctions of endemic wildlife and an overall deterioration of ecosystem functioning (Fischer and Lindenmayer 2007; Lindenmayer, 2008; Magle and Fidino, 2018). Additionally, landscape modifications and disturbances lead to fragmented populations of flora and fauna species, causing direct or indirect changes in community structures and/or behavioural modifications (Berger-Tal and Saltz, 2019). Studies reveal that the type and degree of responses to anthropogenic disturbances are variable and species-specific (Battin, 2004; Villarreal-Barajas and Martorell, 2009; Murphy and Romanuk, 2012; Valiente-Banuet, 2015; Downs et al., 2021). In urban areas, human-wildlife interactions often occur in the interface of green spaces and natural patches of habitats (Kretser et al., 2008; Soulsbury and White, 2016). As urbanisation gradually increases, the relation and complexity of human-wildlife interactions increases as green space (primarily wildlife habitats) shrink (McCleery et al., 2014). Therefore, it is beneficial to scientists, conservation managers and policymakers to examine the spatial ecology of wildlife species persisting in urban mosaic landscapes (Skidmore et al., 2011; Magle et al., 2012).

An animal's available spatial area for its natural activities, such as foraging, reproductivity and parental care, is defined as its home range and is important in understanding

animal ecology (Burt, 1943; Börger, Dalziel and Fryxell, 2008). An animal's home range is its interaction with the physical environment and its movement in the environment. An individual's home range size is influenced by a range of factors, including habitat availability, intrinsic factors (age and sex), its internal state, feeding, biotic interactions (social interactions, group dynamics, territorial behaviour) and other external factors associated with its state and characteristics (Börger et al., 2008; Giuggioli and Kenkre, 2014). The direct link between home range size and habitat use is the movement patterns of an animal's decision to "move" in response to changes in its geographic and environmental space (Van Moorter et al., 2016). Habitat use affects home range size and is facilitated by resource availability and distribution, landscape features and climatic conditions (Van Beest et al., 2011). Variation in home range sizes is species-dependent and generally reflects the habitat quality where resource-rich environments have reduced home ranges (McLoughlin and Ferguson, 2000; Wiegand et al., 2005). Home range and habitat use are important aspects of species ecology to understand species behavioural modifications in changing urban mosaic environments. In recent years, the use of radiotelemetry in spatial ecology studies has dramatically improved to facilitate detailed studies of the behavioural and movement ecology of wild animals such as primates (Cagnacci et al., 2010).

Among the Mammalia, various primate species persist in human-modified environments because of their behavioural flexibility (McKinney, 2015; McLennan, Spagnoletti and Hockings, 2017). Their behavioural diversity is enhanced by their use of bipedalism, brachiation or quadrupedalism, depending on habitat type (Blanchard and Crompton, 2011). The vervet monkey (*Chlorocebus pygerythrus*) (F. Cuvier, 1821) is a medium-sized, niche generalist, semi-terrestrial primate that is persisting despite anthropogenic pressures in South Africa (Patterson, Kalle and Downs, 2017; Thatcher, Downs and Koyama, 2019a; Zungu et al., 2020). They are classified as "Least Concern" in the Red

List of Mammals of South Africa, Swaziland, and Lesotho (Turner et al., 2016) and the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Butynski and de Jong, 2019).

Vervet monkey habitat is broad, including woodland, riverine woodland, savanna, coastal scrub forest, and fragmented habitats, including cultivated areas, rural and urban environments but generally absent from deserts (Smithers, 2012; Turner et al., 2016). These arboreal and terrestrial omnivorous foragers are water-dependent, feeding on various vegetables, fruits, flowers, small insects, some invertebrates, chicks, and eggs (Smithers, 2012; Turner et al., 2016; Butynski and de Jong, 2019). Vervet monkeys live in a social hierarchy of multi-male and multi-female troops, consisting of about 30-70 individuals, having territories with well-defined boundaries and home ranges varying from 5 to 103 ha (Struhsaker, 1967; Smithers, 2012; Turner et al., 2016). There are relatively few natural predatory threats to vervet monkeys in urban areas. However, in the wild, they are preyed upon by crowned (*Stephanoaetus coronatus*), and martial (*Polemaetus bellicosus*) eagles, leopards (*Panthera pardus*), and African rock pythons (*Python sebae*) (Seyfarth and Cheney, 1990; Smithers, 2012; McPherson, Brown and Downs et al., 2016; Grey et al., 2017; Naude et al., 2019).

Despite its widespread nature, the vervet monkey population in KwaZulu-Natal has been affected by numerous anthropogenic activities creating human-wildlife interactions, typically human-monkey conflict (Seoraj-Pillai and Pillay; 2017). They are often persecuted for crop-raiding by farmers (Sillero-Zubiri and Switzer, 2001; Siljander et al., 2020; Findlay and Hill, 2021) or as pests in urban, industrial, and residential gardens where there are direct interactions between humans and monkeys (Healy and Nijman, 2014; Patterson, Kalle and Downs, 2017; Thatcher, Downs and Koyama, 2019a; pers. obs.). Anthropogenic food items and supplemental feeding of vervet monkeys in urban gardens can affect this further (Thatcher, Downs and Koyama, 2019b; Thatcher, Downs and Koyama, 2020). Vervet monkeys

experience unnatural injuries and deaths initiated by these anthropogenic influences and consequential negative human-wildlife interactions (Wimberger, Downs, and Boyes, 2010).

It is fundamental to understand how this common generalist primate species navigate a heterogeneous, human-dominated landscape and uses the urban-natural mosaic landscape to its advantage. We investigated vervet monkeys' spatial ecology to determine the home range and habitat use of individual vervet monkeys across the urban forest mosaic landscape of Durban, eThekwini Municipality, KwaZulu-Natal, South Africa. The data will contribute to sound scientific knowledge that will be applied to decision-making and conservation targets and offer management best practice solutions to reduce human-vervet monkey conflict, particularly in urban areas. Our study used geospatial data and analysis tools to understand spatial-ecological factors of vervets to address human-wildlife interactions that influence the species across the urban forest mosaic landscape. Our study documented the home range and habitat use of vervet monkeys using Global Positioning System (GPS)-Ultra High Frequency (UHF) telemetry transmitters in areas with varying degrees of human disturbance across the urban forest mosaic landscape. We also compared the habitat use of vervet monkey troops occurring in the north and south of the eThekwini Municipality based on preliminary information received from the public and newspaper articles on vervet monkey conflict. Our study provides baseline data for a rehabilitated landfill site (natural) and a residential area (urban) to supplement previous vervet monkey studies in the municipality (Patterson, Kalle and Downs, 2019; Thatcher, Downs and Koyama, 2019a). Additionally, there have been limited spatial ecological studies focused on vervet monkeys in urban-residential, rehabilitated, and/or natural areas; our study aimed to address these gaps. Due to the nature and behavioural plasticity of vervet monkeys, we predicted that home range and habitat use would differ among all the troops of vervet monkeys in an urban forest mosaic landscape of the eThekwini Municipality regardless of their geographic location. We predicted that the size of vervet monkey home ranges would differ in

the Buffelsdraai Regional Landfill site because of the buffer zone and the urban-residential site of Bluff because of anthropogenic influences. We expected that their habitat use would differ across habitat types occurring in the urban forest mosaic landscape in their respective home ranges. We also predicted that vervet monkeys would use forest habitats more than what was available because of alternative food resources.

2.3 Methods

2.3.1 Study area

Our study was conducted in Durban, eThekwini Municipality, South Africa, at two study sites: to the north is Buffelsdraai Regional Landfill Site, and to the south is Treasure Beach, the Bluff (Fig. 2.1). These areas represent the urban forest mosaic landscape that occurs in the region.

The Buffelsdraai Regional Landfill Site (BRLS) (-29.6306, 30.9835) is owned and managed by the eThekwini Municipality. The area of importance in this study is the conservancy area (Conservancy Registration Number C2016/006) of the 2 km buffer zone (787 ha) around the active landfill (116.2 ha). Historically the buffer zone was predominantly used for sugar cane (*Saccharum officinarum*) plantations (Douwes et al., 2015). In 2008, reforestation activities of the buffer zone began with the planting of sixty-one indigenous tree species at a density of approximately 1300 trees/ha (Roy, 2016). Phase two of the forest restoration program took place in 2016 to include existing woodlands, forest, grasslands, wetlands, and riparian areas (Roy, 2016). At the time of the study, there were remanent patches of undisturbed indigenous forest interspersed with alien invasive species and old agricultural patches (Roy, 2016). The forest type of the site is described as Coastal Scarp and Dry Valley Thicket (MacFarlane et al., 2011), and the vegetation is broadly described as belonging to the KwaZulu-Natal Coastal Belt (Mucina and Rutherford, 2006). The summer months (December-February) have the highest precipitation, with an annual rainfall of approximately 766 mm. The

daily average temperatures range from 27.4°C in summer and 22.2°C in winter (Roy, 2016). Although people are present in small numbers all year round, most activities occur in the landfill, the workers' quarters, the nursery, and offices.

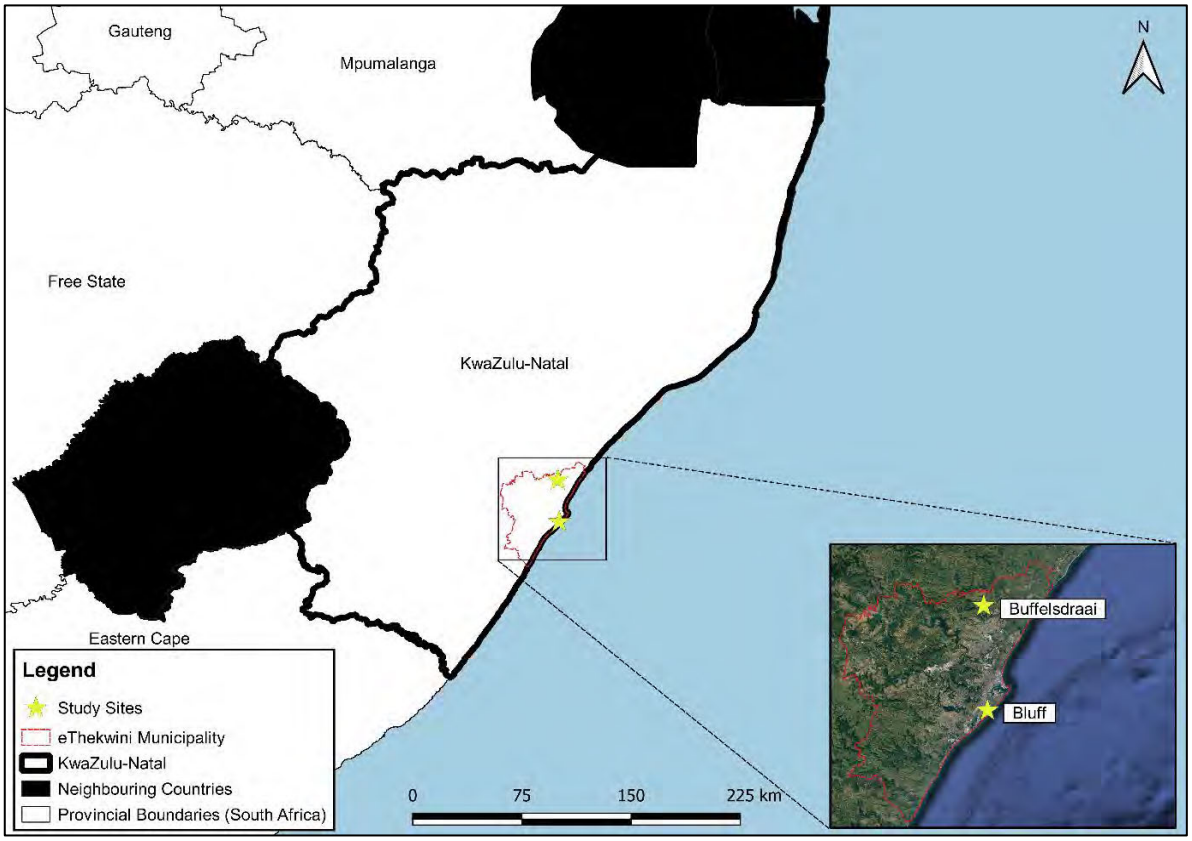


Fig. 2.1. The study area in Durban, eThekwini Municipality, KwaZulu-Natal Province, South Africa, shows the location of the two study sites.

Treasure Beach, Bluff (-29.9466, 30.9949) to the south of Durban, is a suburban, residential area bordering the second-largest crude oil refinery in South Africa. The Bluff is interspersed with coastal lowland forest patches with the Indian Ocean on its periphery. Although there are large pockets of green spaces on the Bluff, the area is predominantly urbanised, with residential areas having large private gardens. Precipitation is highest in the summer months, with an annual mean rainfall of 975 mm. The mean annual minimum and

maximum temperatures are 16.8°C and 24.5°C, respectively (https://en.climate-data.org/africa/south-africa/kwazulu-natal/durban-511/). The approximate population of residents in Treasure Beach are 30 854 (StatSA, 2011).

2.3.2 Vervet monkey trapping, collaring and monitoring procedures

We trapped, immobilised, and fitted eight vervet monkeys from five troops with telemetry collars from July 2016 to July 2018 (Table 2.1). We targeted two individuals from each troop, typically a sub-adult male and an adult female, based on tagging from a previous study (Patterson, Kalle and Downs, 2019) to reflect the troop's spatial ecology. The University of KwaZulu-Natal (no. 020/15/animal) provided animal ethics clearance. Each monkey was captured using a steel walk-in cage trap (70 x 60 x 120 cm), with a pressure pad mechanism that triggered the removable door when a monkey stepped onto it. At dawn, cage traps were baited with commercial fruits (bananas and oranges), peanuts, and raisins placed along a known path that the monkeys frequented (pers. obs.). It was unnecessary to camouflage cage traps as traps were pre-baited seven days before a known trapping event by removing the door - this period allowed the monkeys to become habituated to the traps through the provisioning of food. Traps were monitored hourly until sunset or until a monkey was captured and positively identified as suitable for collaring. All captured monkeys were physically assessed and anaesthetised with an intramuscular injection by a veterinarian using a combination of 0.2 ml/2kg Ketamine® and Domitor® (medetomidine hydrochloride). The effects of the anaesthetic were reversed using Antisedan® (atipamezole hydrochloride). Each captured monkey was aged, sexed, weighed, and its body condition recorded before a transmitter collar was fitted. Additionally, we took photographs for identification, morphological measurements, and faecal, hair and blood samples for DNA. The latter was for another study. We visually identified adult female monkeys (large nipples and canine size), and subadult males were

identified by ageing their canines and smaller body size compared with adult males. Monkeys captured that were either too young or physically too small were released. We calculated the body mass index (BMI) for each vervet monkey from the body mass (in kg) divided by length (in meters) squared (Kavanagh et al., 2011).

The GPS-UHF telemeter collar (WW1500AS-TERRESTRIAL, Animal Trackem, Pietermaritzburg, and Wireless Wildlife, Potchefstroom, South Africa) used on each vervet monkey weighed ~ 60 g, <2% of the body mass of individual monkeys as recommended by Kenward (2001) for animal tracking. We placed a single-finger space gap between the collar and neck of the individual to provide for growth or discomfort if experienced and secured with clear plastic cable ties (100 mm x 2.5 mm), which break away with time. The GPS-UHF telemetry collars were programmed to take four GPS fixes (accuracy 5 – 30 m) at 05h00, 10h00, 15h00 and 20h00, reducing autocorrelation effects (Streicher et al., 2020). Vervet monkeys are diurnal; therefore, the telemeters were switched to 'sleep mode' at night to preserve battery life (Baldellou, 1998).

We downloaded the GPS fixes stored on telemeters using a solar-powered GPS/UHF receiver base station placed at a vantage point (> 6 m) on each study site. Location data were only downloaded when an individual was within range of the base station (5-10 km radius). These data were then uploaded onto a remotely accessed platform, Wireless Wildlife (http://wireless-wildlife.co.za/). Telemeters continued to record GPS fixes until their battery failed. The manufacturer stated that transmitters would function for a minimum of 12 months. However, in our study, all transmitters failed to collect data for a twelve-month cycle, therefore, reducing the duration to seven months. We downloaded data onto a desktop computer for statistical analyses.

2.3.3 Home range and core area estimation

We imported GPS data into ArcGIS 10.6 (ESRI, Redlands, CA, USA) and projected these in Universal Transverse Mercator (UTM) (WGS 1984 UTM Zone 36S). We cleaned the data, removing all outliers or odd GPS fixes manually and tested for site fidelity before analyses. The home range and core area size were estimated using three home range estimates: Maximum Convex Polygon (MCP), Kernel Density Estimator (KDE), and Local Convex Hull (LoCoH) used at the 95% and 50% levels (Worton, 1989; Getz et al., 2007; Laver and Kelly, 2008). We calculated multiple home range estimates using the reproducible home range (RHR) GUI package in statistical software, R Studio (1.2.909) (R Studio, 2015), with hplug-in bandwidth as an appropriate smoothing parameter used for studying species in a highly fragmented landscape like the urban mosaic (Laver and Kelly, 2008; Walter et al., 2011). Using three home range estimates provides accuracy for GPS datasets with high variability and a more unified method for interpretation (Walter et al., 2015; Börger et al., 2020). The 95% MCPs and 95% KDEs were computed onto layers for the two study sites and exported as maps for visual comparisons displaying overlap of home ranges of individual vervet monkeys of the same troop.

2.3.4 Statistical analyses

The home range and core area estimate at 95% and 50% levels were reported respectively for individual vervet monkeys collared using the three home range measures. The overall home range estimates, overall sexes and locations were also reported. Due to the relatively low sample size of vervet monkeys collared, we could not do any further statistical analysis concerning home range and core area use. Additionally, no seasonal comparisons were possible as vervet monkeys were collared at random times in the year, with collars failing to obtain complete seasonal data. The body mass, total body length, and BMI of individual vervet

monkeys caught during trapping were analysed and compared according to sex and location, respectively, using an independent sample t-test. For all statistical analyses, the means (± S.E.) were reported and computed as graphs for visual representation using STATISTICA 7.0 (Statsoft Inc., Tulsa, USA).

2.3.5 Habitat use

Vervet monkey habitat use was determined using GPS data obtained and habitat types documented in the two study sites. A land-use map with a 20 m resolution from Ezemvelo KZN Wildlife (EKZNW) was used (Wildlife and GeoTerraImage, 2018). Habitat types and land use features were reclassified into five broad land-use types: built-up, rehabilitated, forest and thicket, grassland, landfill, and quarry using the South African National Land Cover map (2017). The available habitat type proportions in the respective vervet monkey individual home ranges were determined using ArcGIS 10.6. We added the GPS points from the 95% MCP home range estimates to the reclassified land-use map to determine habitat types for the observed locations (Streicher et al., 2020). We assessed individual vervet monkey habitat use as the observed proportion of locations in the respective land-use types (Gehrt et al., 2009). We compared the habitat use of vervet monkeys with habitat availability in the study sites, and we determined the preference or avoidance of a habitat type. We calculated the selection of habitat types using the null model of the differences between the observed and the expected based on habitat availability (Byers et al., 1984). To determine whether habitat use occurred in proportion to available habitat, we used the Chi-square goodness-of-fit analysis, with differences at the 95-percentage probability level, taken as indicating a significant difference between use and availability. We considered the frequency of the GPS fixes of each vervet monkey in the respective habitats to represent the actual use of these habitat types. We compared the proportion of habitat use with the proportion of habitat availability with the

Bonferroni confidence interval (CI) (Bonferroni Z-statistic) to determine any significant differences for each habitat type (Byers et al., 1984). A significance level of $P < 0.05$ was used to determine significance. Lastly, we quantified each habitat type's percentage use and percentage availability for the vervet monkey population in this study.

2.4 Results

2.4.1 Body mass and condition

Vervet monkeys were captured in an equal ratio sex ratio (n = 10) with an approximate mean age of 2.60 ± 0.47 from five different troops of the eThekwini Municipality, KwaZulu-Natal, South Africa (Table 2.1). The mean body mass of captured vervet monkeys (n = 10) was 3.90 ± 0.39 kg. Male vervet monkeys (4.38 ± 0.91 kg) were on average heavier than female vervet monkey (3.42 ± 0.80 kg), however the difference was not significant ($t(8) = 1.77$, $P = 0.11$) (Fig. 2.2a). The mean total body length for male vervet monkeys were significantly larger to females ($t(8) = 2.43$, $df = 12$, $P < 0.05$) (Fig. 2.2b). Also, the mean BMI did not differ significantly between male and female vervet monkeys ($t(8) = 3.17$, $P = 0.41$) (Fig. 2.2c). The mean body mass for vervet monkeys located on the Bluff was 4.48 ± 1.07 kg and for Buffelsdraai was 3.52 ± 0.71 kg (Fig. 2.2a). The mean total body length for vervet monkeys captured on the Bluff was 113.88 ± 4.19 cm, while for Buffelsdraai, 113.85 ± 7.00 cm. The mean BMI for captured vervet monkeys on the Bluff was 3.43 ± 0.71 cm, while at Buffelsdraai, 2.70 ± 0.42 kg/m^2. There were no significant differences between study sites for captured vervet monkey body mass ($t(8) = 1.72$, $P = 0.12$), total body length ($t(8) = 0.01$, $P = 0.99$) and BMI ($t(8) = 2.06$, $P = 0.07$). The overall mean troop size ($n = 5$) of vervet monkeys from which individuals were captured in the eThekwini Municipality was 29.80 ± 4.35 (Table 2.1).

Table 2.1 Details of individual vervet monkeys (*n* = 10) captured at two study sites (Buffelsdraai and the Bluff) within the urban forest mosaic landscape of eThekwini Municipality, South Africa. (Ind = individual identity; Buffels = Buffelsdraai; age was an approximate; BMI = body mass index).

ID	Sex	Study site	Troop name	Troop size	Age in years	Body mass (kg)	Total body length (cm)	BMI (kg/m^2)
VM 1	Male	Bluff	WESSA	18	5	5.2	114.5	3.97
*VM 2	Female	Bluff	WESSA	18	2	4.7	111.5	3.78
*VM 3	Male	Buffels	BD_Resident	45	2	4.0	123.6	2.62
*VM 4	Female	Buffels	BD_Mad	30	3	3.4	113.0	2.66
*VM 5	Male	Bluff	Engen	15	5.5	5.1	119.5	3.57
VM 6	Female	Bluff	Engen	15	1.5	2.9	110.0	2.40
*VM 13	Female	Buffels	BD_Resident	45	2	3.5	105.0	3.17
*VM 14	Female	Buffels	BD_Nursery	22	2	2.6	112.0	2.07
VM 0	Male	Buffels	BD_Resident	45	1	4.6	120.5	3.17
VM 00	Male	Buffels	BD_Resident	45	2	3.0	109.0	2.53

* Individuals utilised for home range analysis

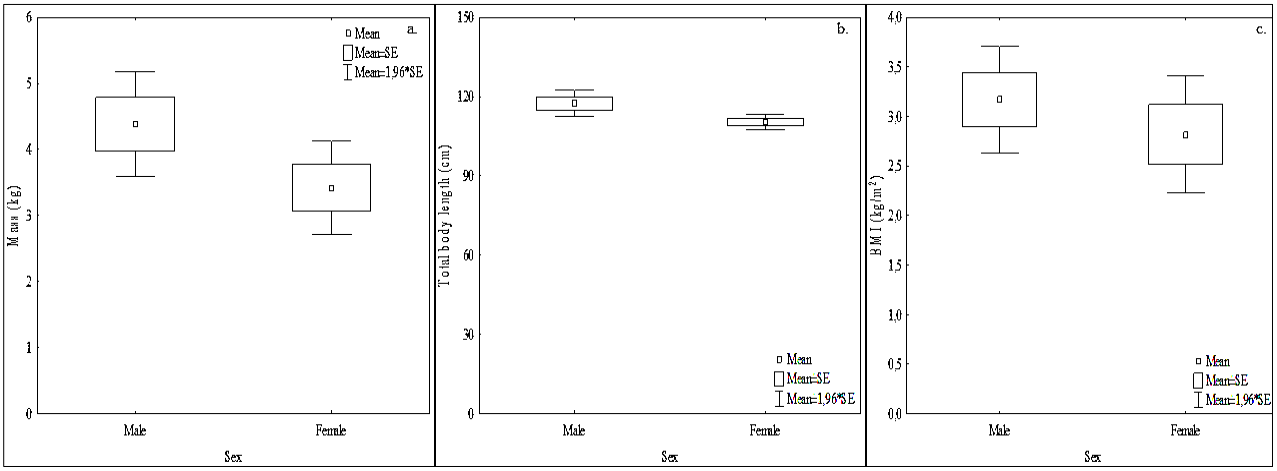


Fig. 2.2 Overall mean (± S.E.) of a. body mass and b. total body length and c. body mass index (BMI) of captured vervet monkeys (*n* = 10) according to sex in the present study.

2.4.2 Home range and core area estimation

A total of eight vervet monkeys were captured and fitted with GPS-UHF tracking collars; however, only six had sufficient data to be analysed. Consequently, we determined home range estimates for six collared vervet monkeys (four females and two males) from the two locations in the urban forest mosaic landscape in eThekwini Municipality between November 2016 and March 2018 (Table 2.2). These included four females (VM2, VM4, VM13, VM14) and two males (VM3, VM5). The number of GPS fixes from collared vervet monkeys ranged from 59 to 446, varying individually. Over time the GPS-UHF tracking collars began to lose power and eventually stopped obtaining GPS fixes (Table 2.2). A total of 1492 GPS fixes were recorded during the duration of this study for the collared vervet monkeys. The mean number of days for reporting GPS fixes from collared vervet monkeys was 127.3 ± 16.86 days (Table 2.2).

The three home range estimates for vervet monkeys showed individual variation in home range and core area size (Fig. 2.3a-b). The overall mean of the 95% home range (± S.E.) for vervet monkeys (n = 6) was 47.27 ± 16.04 ha (MCP), 30.73 ± 8.10 ha (KDE), and 22.95 ± 7.00 ha (LoCoH). The overall core area at the mean 50% core range for vervet monkeys was 17.39 ± 5.51 ha (MCP), 6.52 ± 1.44 ha (KDE) and 3.59 ± 1.08 ha (LoCoH) (Fig. 2.3c). On average, male vervet monkeys had a slightly more extensive home range than female vervet monkeys for all three home range estimates (Supplementary Fig. S2.1a), whereas the 50% core area for vervet monkeys showed marginally larger sizes for female than male vervet monkeys (Supplementary Fig. S2.1b). Overall, the means of the 95% home range (Supplementary Fig. S2.1c) and 50% core area (Supplementary Fig. S2.1d) for vervet monkeys were larger at Buffelsdraai than at Bluff (Supplementary Fig. S2.2). The troops that had two individuals tracked, revealed data with similar spatial patterns, supporting that the individual reflected the troop's movements.

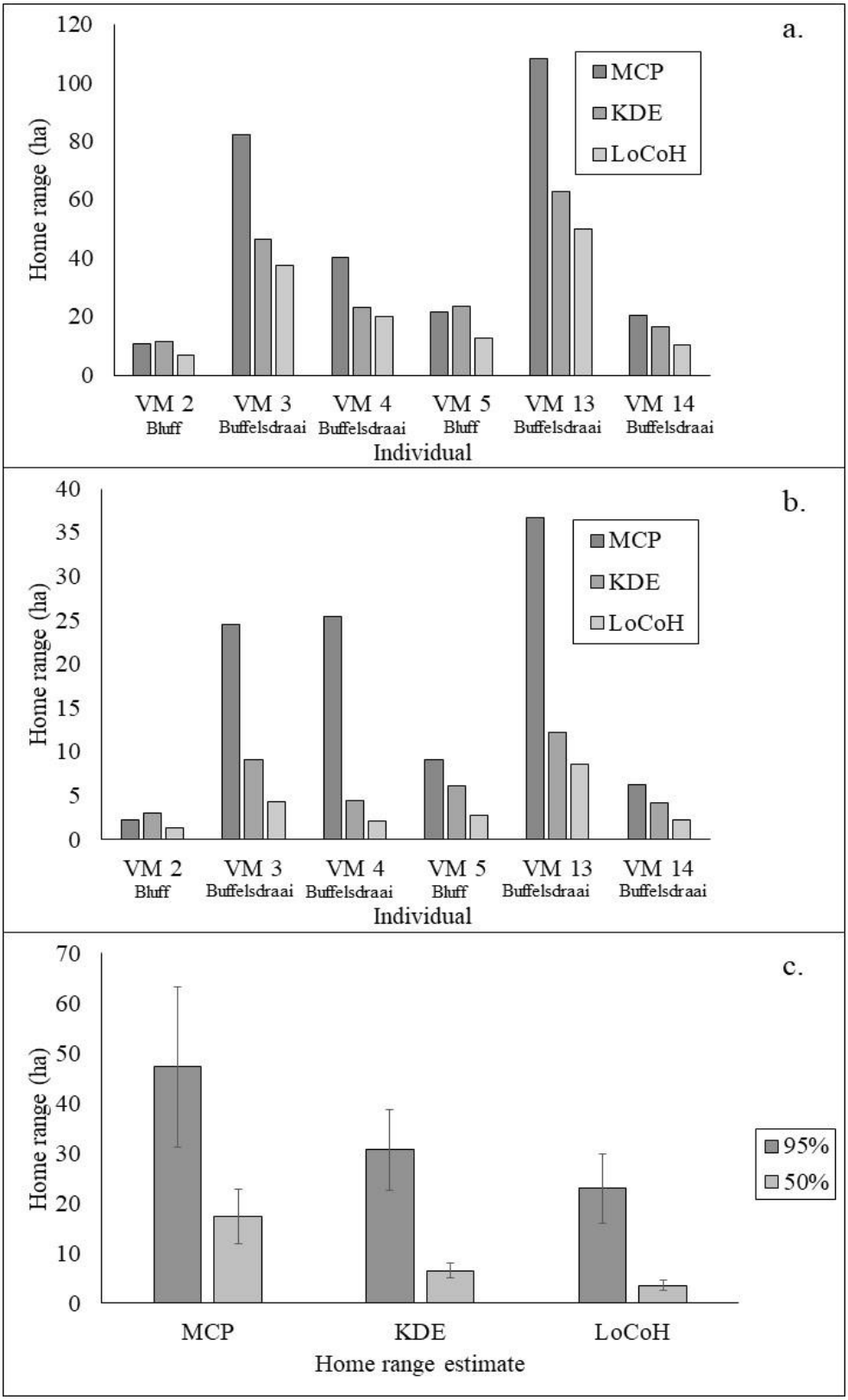


Fig. 2.3 Home range of vervet monkeys in an urban mosaic landscape where a. shows individual home range (V.M., *n* = 6) at 95 % home range estimates; b. individual home range of vervet monkeys (V.M., *n* = 6) at 50 % home range estimates and c. the overall mean home range (± S.E.) of the three home range estimates (Maximum Convex Polygon (MCP), Kernel Density Estimate (KDE) and Local Convex Hull (LCH)) in the present study for all collared vervet monkeys.

2.4.3 Habitat use

Overall, vervet monkeys in the eThekwini Municipality showed a significant preference for forest and thicket habitats, as revealed by the Bonferroni Z-statistic computations (Table 2.3). Built-up and grassland habitats were used by vervet monkeys proportionate to the available habitat. Built-up areas were used by all vervet monkeys regardless of availability. Landfill and quarry appear to be avoided by two vervet monkeys as these were used significantly less than available. However, overall, the landfill and quarry had no effect on use in proportion to availability by most of the vervet monkeys. Rehabilitated land mainly was used proportionate to the availability and used significantly less by vervet monkey V.M. 4 in Buffelsdraai. Vervet monkey V.M. 2 did not affect the preference for any habitat type available in Bluff, and vervet monkey V.M. 5 did not affect the preference for rehabilitated landfill and quarry on the Bluff as this habitat type did not exist (Table 2.3). The overall percentage of land-use type by vervet monkeys was higher for forest and thicket, and built-up, which were used more than available, whereas grassland and rehabilitated land-use types were used less than available. Mines and quarries were significantly used less than available (Fig. 2.4).

Table 2.2 Home range and core area estimates of individual vervet monkeys (n = 8) collared with GPS/UHF transmitters from five troops in the urban forest landscape mosaic in eThekwini Municipality, South Africa.

Individual	Sex	Location	Start Date	End Date	Tracking period (days)	No. of GPS fixes	95 % MCP (ha)	95% KDE (ha)	95% LoCoH (ha)	50% MCP (ha)	50% KDE (plug-in) (ha)	50% LoCoH (k) (ha)
VM 1	Male	Bluff	2017/07/19	NR	NR	NR	NR	NR	NR	NR	NR	NR
VM 2	Female	Bluff	2017/07/19	2017/09/24	68	59	10.67	11.35	7.06	2.21	2.99 (21.42, 18.79)	1.34 (8)
VM 3	Male	Buffelsdraai	2016/11/23	2017/05/20	179	446	82.18	46.69	37.66	24.59	9.12 (17.29, 26.49)	4.37 (21)
VM 4	Female	Buffelsdraai	2016/11/23	2017/05/10	169	298	40.28	23.07	20.18	25.44	4.41 (14.38, 24.13)	2.17 (17)
VM 5	Male	Bluff	2017/02/28	2017/06/29	122	166	21.57	23.72	12.54	9.17	6.17 (29.61, 24.79)	2.74 (13)
VM 6	Female	Bluff	2017/03/01	NR	NR	NR	NR	NR	NR	NR	NR	NR
VM 13	Female	Buffelsdraai	2018/03/13	2018/07/12	122	291	108.37	62.88	49.86	36.68	12.26 (18.68, 33.38)	8.63 (17)
VM 14	Female	Buffelsdraai	2018/03/21	2018/07/02	104	231	20.54	16.70	10.45	6.27	4.19 (21.56, 15.44)	2.29 (15)
Mean					**127.33**	**248.50**	**47.27**	**30.73**	**22.95**	**17.39**	**6.52**	**3.59**

N.R.: not recorded

Table 2.3 Available and used habitat types of vervet monkey individuals in the urban forest landscape mosaic in eThekwini Municipality, South Africa.

	Bluff		Buffelsdraai			
Monkey ID	VM 2	VM 5	VM 3	VM 4	VM 13	VM 14
Built-up	NIL	±	±	+	±	±
Rehabilitated	NIL	NIL	±	-	+	±
Forest and thicket	NIL	-	+	+	+	+
Grassland	NIL	-	±	±	±	±
Landfill and quarry	NIL	NIL	-	NIL	-	NIL

Note: "NIL" denotes no effect on used or available habitat, a plus sign "+" indicates that the ratio of used habitat was greater than the available habitat, a minus sign "-" indicates the ratio of used habitat was less than the available habitat, and the sign "±" indicates the used and available habitat was in proportion (according to Chi-square test, $P < 0.05$).

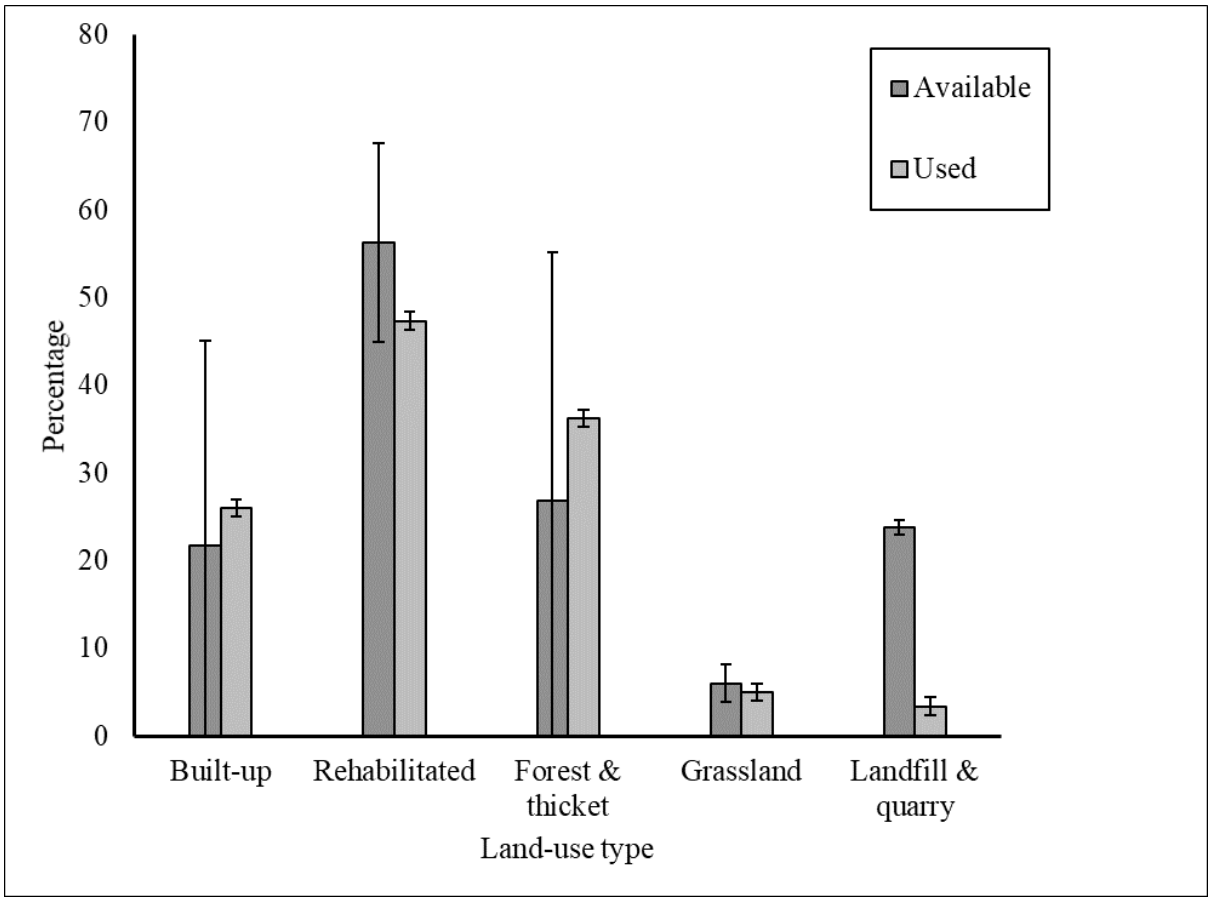


Fig. 2.4 Overall mean percentage (± S.E.) of available and used land-use types of vervet monkeys in the urban forest mosaic landscape in the present study.

2.5 Discussion

2.5.1 Body mass and condition

This study used telemetry systems to determine the spatial ecology of vervet monkeys across the urban forest mosaic landscape from two locations in the eThekwini Municipality, KwaZulu-Natal, South Africa. Vervet monkeys reported in this study were similar in body mass when compared to other urban-living monkeys in the province of KwaZulu-Natal, South Africa (Patterson, Kalle and Downs 2019). However, when comparing sexes to previous studies (Turner et al., 2018; Patterson, Kalle and Downs 2019), males and females across an urban forest mosaic in this study had an overall lower body mass compared to the previous studies. The vervet monkeys from these two study sites differed in body mass by 27%, suggesting that habitat types could be partly responsible for the body condition of vervet monkeys. The morphological aspects of vervet monkeys are known to be influenced by many environmental conditions, food consumption, competition, and social dynamics in vervet monkeys (Pasternak et al., 2013; Turner et al., 2016, 2018; Jarrett et al., 2020). When comparing locations in this study, Buffelsdraai vervet monkeys weighed less than the Bluff vervet monkeys. This could be because of the larger span of home ranges at Buffelsdraai the vervet monkeys utilise in their daily routes resulting in more physical activities, lower masses and leaner monkeys than those in the urban-residential Bluff site, where monkeys were observed having an artificial diet (pers. obs.).

2.5.2 Home range and core area estimation

Our study reports the home range and habitat use of vervet monkeys using telemeters across an urban forest mosaic landscape of varying degrees of anthropogenic activities in the eThekwini Municipality. The three home range methods (MCP, KDE, and LoCoH) used to calculate the vervet monkeys' home-range size produced different estimates, although the core

range area estimates varied less. Harvey and Clutton-Brock (1981) suggest *Cercopithecus* species have unusually small home ranges based on their metabolic needs. In the present study, mean home range sizes (47.27 ha 95% MCP) and core sizes (6.52 ha 50% KDE) were small when compared with previous vervet monkey studies in South Africa (De Moor and Steffens 1972; Barrett 2004a; 2009b; Willems, 2007; Pasternak et al., 2013; Patterson et al., 2019; Supplementary information Table S2.1.). Individual home ranges of vervet monkeys collared in our study illustrated varying sizes but were similar in size to troops collared in the same region (Patterson, Kalle and Downs, 2019). Vervet monkey movements in these contrasting environments were indicative of different environmental structures and human-induced activities, suggesting that the urban forest mosaic landscape impacted vervet monkeys' spatial ecology. It is possible that vervet monkey movements are based on its use of cognitive heuristics on available resources (Teichroeb 2015a). Additionally, vervet monkey movement data displayed a distinctive home range pattern according to its location (Supplementary Fig. S1b).

Our study also showed that vervet monkeys are territorial and that troops' daily movements range exclusively in specific areas (Supplementary Fig. S2.2). The home range for male vervet monkeys presented slightly larger home ranges than females. However, for core area estimates, female vervet monkeys showed a slightly larger range than their male counterparts. A larger core can be explained by female vervets exhibiting tight bonds and philopatry in the social hierarchy of the troop (Seyfarth 1980; Cheney and Seyfarth 1990). In addition, females exhibit familiarity with an area, frequently nursing babies, teaching juveniles how to forage and protect young, leading to larger and longer time spent in core areas (Isbell, 2004). Male vervet monkeys typically warn the troop by being vigilant for predators and making alarm calls or defending territories from neighbouring troops suggestive of larger home ranges (Henzi, 1982; Baldellou and Henzi, 1992; Ducheminsky, Henzi and Barrett, 2014;

Snowdon, 2020). Vervet monkeys had a more extensive home range and core area sizes in Buffelsdraai than in the Bluff study site. It is evident that the primary factor determining vervet monkeys' spatial use is food resource availability linked to anthropogenic disturbances and infrastructure (Willems et al., 2009; Patterson, Kalle and Downs, 2018). The Bluff is a suburban residential area with fragments of natural space, so anthropogenic infrastructure (roads, fences, telephone lines, and residential homes) affect vervet monkeys' movement. Furthermore, we observed that vervet monkeys on the Bluff were prone to dog attacks, shooting by people, and vehicle collisions (Authors unpublished data). In contrast, at Buffelsdraai, large forest corridors, rehabilitated old sugar cane plots, and grasslands with reduced human presence allow for greater mobility by vervet monkeys (pers. obs.).

Although we did not examine food resources across the urban forest mosaic landscape, the concentration of anthropogenic resources in urban areas is also likely to contribute to a decreased home range size. Our results suggest that vervet monkeys did not need to travel extensively for food in the urban residential areas of Bluff. Artificial food sources are easily attainable in urban areas where people do not manage their waste properly and find that vervet monkeys are foraging through rubbish bins or raiding kitchens when the opportunity arises (pers. obs.). Based on optimal foraging theory, as described by Barrett et al. (2016), vervet monkeys are energy maximisers, selecting resource items in proportion to their energy content irrespective of the variety of resources available in their environment. Regardless of the level of anthropogenic disturbance in both study sites, vervet monkeys showed considerable behavioural and diet flexibility in the present study. Our results suggest that vervet monkeys adjusted their use of food resources and intensively used specific areas within their home range where the most nutrient-rich or any available resources were present, and predictably available as found in other urban primate studies (Riley 2008; Hoffman and O'Riain, 2012; McLennan, Spagnoletti and Hockings 2017; Thatcher, Downs and Koyama, 2020).

We found that the troop size of vervet monkeys differed in locations of urban-residential and transformed natural areas in this study. The troop sizes on the Bluff were smaller and had smaller home ranges, whereas the Buffelsdraai troops had larger troop sizes and more extensive home ranges. Generally, larger troops require large space to obtain food since intergroup competition forces individuals to travel further and forage over a greater area, similar to the area exhibited at Buffelsdraai (Mikula et al., 2018; Teichroeb et al., 2015b). Additionally, the widespread food and cover resources for vervet monkeys allow troops to have larger home ranges in areas where woody plant species and larger canopies occur, similarly observed in the vervet monkeys at Buffelsdraai (Barrett et al., 2016). In addition, vervet monkeys live in hierarchical social groups interacting gregariously with various age classes in the troop and communicating about predators and high-quality food resources (Swedell 2012). However, urban vervet monkey troops are at risk of unnatural causes and are exposed to numerous negative human-wildlife interactions, resulting in smaller troop sizes, as seen on the Bluff (Saj, 1998; Wimberger and Downs, 2010; Pasternak et al., 2013). The smaller troop sizes in the Bluff could also be because of the urban residential environment it exists in, with limited free pathways and many anthropogenic activities such as domestic pets and traffic that are known to impact the survival of vervet monkeys (Wimberger and Downs, 2010). Additionally, the human-wildlife conflict experienced between people and the vervet monkeys has been reported numerously in the media (pers. obs.).

2.5.3 Habitat use

Our study highlighted the habitat use of vervet monkeys across an urban forest mosaic landscape. As predicted, there were differences in habitat use of vervet monkeys living in this landscape. The forest and thicket, and built-up habitat types were used more frequently than other land-use types in the landscape. Furthermore, habitat use of vervet monkeys in

Buffelsdraai showed extensive usage of forest and thicket habitat types over rehabilitated and landfill and quarry areas. Buffelsdraai vervet monkeys also used built-up and grassland habitat types in proportion to availability, possibly maximising foraging efforts and supplementing their diets with anthropogenic food. Habitat type for vervet monkeys on the Bluff had minimal effect on habitat use, apart from forest and thicket and grassland being used less than available and built-up used in proportion. The flexibility in habitat use suggests that these vervet monkeys can potentially persist in urban environments without a dependency on natural habitats. These results further showed the vervet monkey's behavioural flexibility in habitat use in an urban mosaic landscape.

South African law requires a buffer zone around an active landfill to obscure the view and shield any odours associated with landfill operations protecting any adjacent community. The rehabilitation of transformed areas at Buffelsdraai Regional Landfill Site has been a conservation success by increasing indigenous species richness (flora and fauna) (Roy, 2016). MacFarlane et al. (2011) reported substantially less biodiversity in transformed areas when compared with remnant patches of untransformed land. Although a considerable proportion of the land has been converted to rehabilitated land, vervet monkeys still preferred forested and thicket habitats, possibly because of a lack of competitors and accessibility to energy-rich food resources (Isabell et al., 1990; Saj et al., 1999). The vervet monkey collared in the nursery troop had the smallest home range yet spent the most time in the natural forest. With large canopy trees and dense bush, forest productivity is important to primates because it provides food and covers protection from predation (Horwich et al., 1993; Cheyne, 2009). The habitat types of forest and thicket, and grassland used by vervet monkeys at Buffelsdraai exhibited the importance of the buffer zone. Although natural food was available, this did not deter the monkeys from foraging in built-up areas, raiding bins and the staff kitchen, as we observed from the two troops that shared the area at separate times and days (pers. obs.).

Two troops at Buffelsdraai (BD_Resident and BD_Mad) displayed considerable overlap in home ranges (Supplementary information Fig. S 2.2). However, at no identical time did these troops overlap (pers. obs.). Vervet monkeys are known to be absentee owners in cases where "territories can be nonexclusive but may still be perceived by themselves as sole-owned, as neighbours only intrude when territory owners are absent from that area" (Isabell et al., 2021), as was evident in our study. The rehabilitation of the landfill in Buffelsdraai appeared not directly beneficial for the vervet monkeys; however, it provided increased connectivity between habitat types in the adjoining landscape, facilitating dispersal and the movement of individuals. Furthermore, the increase in habitat and food available from the existing forest habitats may increase carrying capacity and troop size. The relative lack of human activity allows these populations to mimic wild troop numbers (Isbell et al., 1990; Barrett et al., 2016). However, with highly modified landscapes, vervet monkeys will exploit and use the environment to fulfil their instinctive nature and behaviour. In South Africa, vervet monkeys are protected by law, provided that they are not marked as Damage Causing Animals (DCAs). Therefore to avoid conflict between vervet monkeys and people living in the municipality, there is a need to effectively manage anthropogenic waste by securing refuse bins, plant more indigenous trees, and reassess housing and industrial developments without reducing the extant natural forests occurring along the urban forest landscape, whilst existing collectively with all wildlife. Our study provides insight into the spatial ecology and habitat use of vervet monkeys in an urban mosaic landscape. Space requirements for human population growth in urban areas will continue to increase; therefore, future development for residential and commercial demands will need to retain natural habitat types to sustain wildlife populations and avoid negative human-wildlife interactions. The study is the first comparative analogy of spatial movement (home range and habitat use) of vervet monkeys depicting troop movements across an urban forest mosaic landscape with GPS-UHF tracking collars. Vervet monkeys exist in

troops of hierarchal levels, providing researchers remote access to data using GPS-UHF tracking collars. Additionally, we are limiting human interaction and presence, providing a clear pattern of the species' spatial ecology in its natural habitat. Although expensive and with limitations concerning battery lifespan relative to its collar weight, the use of GPS-UHF tracking collars provides overall high quality and quantity of reliable data for primates (Dore et al. 2020). Our study's technical limitations from the GPS-UHF tracking collars yielded limited data. In addition, the low success of working collars considers it necessary to increase the sample size to understand vervet monkeys' spatial movements comprehensively. Therefore, we recommend future studies on increasing the number of remote-tracking collars to identify fine resolution spatial patterns regarding seasonal variation and individual overlapping of this primate species.

2. 5.4 Conclusions

The home range and habitat use of vervet monkeys living in the urban forest interface alongside humans showed individual variation and differences in movement patterns. These semiarboreal primates use the urban and forest habitats while navigating successfully through the anthropogenic landscape. However, vervet monkeys in urban areas need management intervention to reduce negative human-wildlife interactions. To protect the status of the species and limit human-monkey interaction, possible management methods are suggested. The inclusion and enforcement of national legislation and provincial by-laws to protect the species from human threats is crucial for regulating keeping primates as pets, animal welfare and feeding. Implementing a complete ban on anthropogenic food provision for primates is paramount to avoid welfare and wellbeing implications for vervet monkeys caused by inevitable conflicts (pet attacks, poisoning or shooting). Management practices to conceal waste and human food to avoid possible raiding events are also required. The future of urban

planning in tackling negative human-wildlife interactions is justified through environmental education of the above management practices. A requirement of the public involves active engagement and education on the importance and value of coexisting with wildlife, especially with an indigenous primate such as the vervet monkey.

2.6 Acknowledgements

We are grateful for financial support from the National Research Foundation (ZA, Grant 98404) and Ethekwini Durban Research Action Partnership (DRAP, ZA). We thank the Ford Wildlife Foundation (ZA) for vehicle support. Special thanks to F. Moolla and R. Winn at Buffelsdraai Landfill Conservancy; and WESSA Treasure Beach Educational Centre for providing permission and access to the study sites. Dr S. Singh (veterinarian) is thanked for enabling capturing and collaring of vervet monkeys. We thank V. Hugo for technical assistance during the tracking of the vervet monkeys and K. Josiah for creating graphic representations of maps. We thank M. Machawe for his comments on the draft manuscript. Ethical clearance was obtained from the University of KwaZulu-Natal to catch and fit transmitters on the vervet monkeys.

2.7 References

Baldellou M, Adan A (1998) Diurnal and seasonal variations in vervet monkeys' activity. Psychol Rep 83:675-685. https://doi.org/10.2466%2Fpr0.1998.83.2.675

Baldellou M, Henzi SP (1992) Vigilance predator detection and the presence of supernumerary males in vervet monkey troops. Anim Behav 43:451-461. https://doi.org/10.1016/S0003-3472(05)80104-6

Bar-Massada A, Radeloff VC, Stewart SI (2014) Biotic and abiotic effects of human settlements in the wildland-urban interface. Bioscience 64:429-437. https://doi.org/10.1093/biosci/biu039

Barrett AS, Barrett L, Henzi P, Brown LR (2016) Resource selection on woody plant species by vervet monkeys (*Chlorocebus pygerythrus*) in mixed-broad leaf savanna. Afr J Wildl Res 46:14-21. https://hdl.handle.net/10520/EJC186959

Barrett AS (2004) Foraging ecology of the vervet monkey (*Chlorocebus aethiops*) in mixed lowveld bushveld and sour lowveld bushveld of the Blydeberg Conservancy Northern Province South Africa. Dissertation, University of South Africa.

Barrett AS (2009) Spatial and temporal patterns in resource dispersion and the structure of range use and coexistence in a social omnivore (Chlorocebus aethiops). Dissertation, University of South Africa.
Battin J (2004) When good animals love bad habitats: ecological traps and the conservation of animal populations. Conserv Biol 18:1482-1491. https://doi.org/10.1111/j.1523-1739.2004.00417.x
Berger-Tal O, Saltz D (2019) Invisible barriers: anthropogenic impacts on inter- and intra-specific interactions as drivers of landscape-independent fragmentation. Philos T Roy Soc B 374:1-9. https://doi.org/10.1098/rstb.2018.0049
Blanchard ML, Crompton RH (2011) Field study methods for primate locomotor ecology and biomechanics. In: D'Août K, Vereecke EE (ed) Primate Locomotion, Springer, New York, pp 183-199.
Bolter DR, Zihlman AL (2003) Morphometric analysis of growth and development in wild-collected vervet monkeys (*Cercopithecus aethiops*) with implications for growth patterns in Old World monkeys apes and humans. J Zool 260:99-110. https://doi.org/10.1017/S0952836903003522
Börger L, Dalziel BD, Fryxell JM (2008) Are there general mechanisms of animal home range behaviour? A review and prospects for future research. Ecol Lett 11:637-650. https://doi.org/10.1111/j.1461-0248.2008.01182.x
Börger, L., Fieberg, J., Horne, J., Rachlow, J., Calabrese, J., & Fleming, C. (2020). Animal Home Ranges: Concepts, Uses, and Estimation. In D. L. Murray & B. K. Sandercock (ed) Population Ecology in Practice, New Jersey: John Wiley & Sons, pp 315-332.
Brueckner JK (2000) Urban sprawl: diagnosis and remedies. Int Regional Sci Rev 23:160-171. https://doi.org/10.1177%2F016001700761012710
Burt WH (1943) Territoriality and home range concepts as applied to mammals. J Mammal 24: 346-352. https://www.jstor.org/stable/1374834
Butynski TM, de Jong YA (2019) *Chlorocebus pygerythrus* The IUCN Red List of Threatened Species: e-T136271A17957823. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T136271A17957823.en
Byers CR, Steinhorst RK, Krausman PR (1984) Clarification of a technique for analysis of utilization-availability data. J Wildlife Manage 48:1050-1053. https://doi.org/10.2307/3801467
Cagnacci F, Boitani L, Powell RA, Boyce MS (2010) Animal ecology meets GPS-based radiotelemetry: a perfect storm of opportunities and challenges. Philos T Roy Soc B 365:2157-2162. https://doi.org/10.1098/rstb.2010.0107
Cheney DL, Seyfarth RM (1990) How monkeys see the world: Inside the mind of another species. University of Chicago Press, United States of America
De Moor PP, Steffens FE (1972) The movements of vervet monkeys (*Cercopithecus aethiops*) within their ranges as revealed by radio-tracking. J Anim Ecol 41:677-687. https://doi.org/10.2307/3202
Dore KM, Hansen MF, Klegarth AR et al. (2020) Review of GPS collar deployments and performance on nonhuman primates. Primates 61:1-15. https://doi.org/10.1007/s10329-020-00793-7
Douwes E, Roy KE, Diederichs-Mander N et al. (2015) The Buffelsdraai Landfill Site Community Reforestation Project: leading the way in community ecosystem-based adaptation to climate change. eThekwini Municipality, South Africa
Ducheminsky N, Henzi SP, Barrett L (2014) Responses of vervet monkeys in large troops to terrestrial and aerial predator alarm calls. Behav Ecol 25:1474-1484. https://doi.org/10.1093/beheco/aru151

Findlay LJ, Hill RA (2021) Baboon and vervet monkey crop-foraging behaviors on a commercial South African farm: preliminary implications for damage mitigation. Hum Wildl Inter 14:505-518.
Fischer J, Lindenmayer DB (2007) Landscape modification and habitat fragmentation: a synthesis. Global Ecol Biogeogr 16:265-280. https://doi.org/10.1111/j.1466-8238.2007.00287.x
Gehrt SD, Anchor C, White LA (2009) Home range and landscape use of coyotes in a metropolitan landscape: conflict or coexistence? J Mammal 90:1045-1057. https://doi.org/10.1644/08-MAMM-A-277.1
Getz WM, Fortmann-Roe S, Cross PC et al. (2007) LoCoH: nonparameteric kernel methods for constructing home ranges and utilization distributions. PloS One 2:1-11. https://doi.org/10.1371/journal.pone.0000207
Giuggioli L, Kenkre VM (2014) Consequences of animal interactions on their dynamics: emergence of home ranges and territoriality. Mov Ecol 2:1-22. https://doi.org/10.1186/s40462-014-0020-7
Grey JNC, Bell S, Hill RA (2017) Leopard diets and landowner perceptions of human wildlife conflict in the Soutpansberg Mountains South Africa. J Nat Conserv 37:56-65. https://doi.org/10.1016/j.jnc.2017.03.002
Harvey P, Clutton-Brock T (1981) Primate home-range size and metabolic needs. Behav Ecol Sociobiol 8:151-155. https://www.jstor.org/stable/4599372
Healy A, Nijman V (2014) Pets and pests: vervet monkey intake at a specialist South African rehabilitation centre. Anim Welfare 23:353-360. https://doi.org/10.7120/09627286.23.3.353
Hemelrijk CK, Wubs M, Gort G et al. (2020) Dynamics of intersexual dominance and adult sex-ratio in wild vervet monkeys. Front Psychol 839:1-11 https://doi.org/10.3389/fpsyg.2020.00839
Henzi SP (1982) Some aspects of visual signalling and social organization in the vervet monkey (*Cercopithecus aethiops pygerythrus*) Dissertation, University of KwaZulu-Natal
Hoffman TS, O'Riain MJ (2012) Landscape requirements of a primate population in a human-dominated environment. Front Zool 9:1-17. https://doi.org/10.1186/1742-9994-9-1
Isbell LA (2004) Is There No Place Like Home? Ecological Bases of Female Dispersal and Philopatry and Their Consequences for the Formation of Kin Groups. In: Chapais B, Berman CM (ed) Kinship and Behavior in Primates. Oxford University Press, New York, pp 71-108
Isbell LA, Bidner LR, Loftus JC et al. (2021) Absentee owners and overlapping home ranges in a territorial species. Behav Ecol Sociobiol 75:1-14. https://doi.org/10.1007/s00265-020-02945-7
Isbell LA, Cheney DL, Seyfarth RM (1990) Costs and benefits of home range shifts among vervet monkeys (*Cercopithecus aethiops*) in Amboseli National Park Kenya. Behav Ecol Sociobiol 27:351-358. https://doi.org/10.1007/BF00164006
Jarrett JD, Bonnell T, Jorgensen MJ et al. (2020) Modeling variation in the growth of wild and captive juvenile vervet monkeys in relation to diet and resource availability. Am J Phys Anthropol 171:89-99. https://dx.doi.org/10.1002%2Fajpa.23960
Kavanagh K, Dozier BL, Chavanne TJ et al. (2011) Fetal and maternal factors associated with infant mortality in vervet monkeys. J of Med Primatol 40:27-36. https://dx.doi.org/10.1111%2Fj.1600-0684.2010.00441.x
Kenward RE (2001) Historical and Practical Perspectives. In: Millspaugh JJ, Marzluff JM (ed) Radio Tracking and Animal Populations. Academic Press, London, pp 3-12

Kenward RE (2001) A Manual for Wildlife Tagging. Academic Press, New York
Kretser HE, Sullivan PJ, Knuth BA (2008) Housing density as an indicator of spatial patterns of reported human-wildlife interactions in Northern New York. Landscape Urban Plan 84:282-292. https://doi.org/10.1016/j.landurbplan.2007.08.007
Laver PN, Kelly MJ (2008) A critical review of home range studies. J Wildlife Manage 72: 290-298. https://doi.org/10.2193/2005-589
Lindenmayer DB, Fischer J, Felton A et al. (2008) Novel ecosystems resulting from landscape transformation create dilemmas for modern conservation practice. Conserv Lett 1:129-135. https://doi.org/10.1111/j.1755-263X.2008.00021.x
MacFarlane D, Harvey J, Hamer M (2011) Biodiversity Assessment of the Buffelsdraai Landfill Site Community Reforestation Programme, Report No E P 08-01. eThekwini Municipality, South Africa
Magle SB, Fidino M (2018) Long-term declines of a highly interactive urban species. Biodivers Conserv 27:3693-3706. https://doi.org/10.1007/s10531-018-1621-z
Magle SB, Hunt VM, Vernon M, Crooks KR (2012) Urban wildlife research: past present and future. Biol Conserv 155:23-32. https://doi.org/10.1016/j.biocon.2012.06.018
McCleery RA, Moorman CE, Peterson MN (2014) Urban wildlife conservation: theory and practice Springer, New York
McKinney ML (2006) Urbanization as a major cause of biotic homogenization. Biol Conserv 127:247–260. https://doi.org/10.1016/j.biocon.2005.09.005
McKinney T (2015) A classification system for describing anthropogenic influence on nonhuman primate populations. Am J Primatol 77:715–726. https://doi.org/10.1002/AJP.22395
McLennan MR, Spagnoletti N, Hockings KJ (2017) The implications of primate behavioral flexibility for sustainable human-primate coexistence in anthropogenic habitats. Int J Primatol 38:105-121. https://doi.org/10.1007/s10764-017-9962-0
McLoughlin P D, Ferguson S H (2000) A hierarchical pattern of limiting factors helps explain variation in home range size. Ecoscience 7:123-130. https://doi.org/10.1080/11956860.2000.11682580
McPherson SC, Brown M, Downs CT (2016) Diet of the crowned eagle (*Stephanoaetus coronatus*) in an urban landscape: potential for human-wildlife conflict? Urban Ecosyst 19:383-396. https://doi.org/10.1007/s11252-015-0500-6
Mikula P Šaffa G Nelson E, Tryjanowski P (2018) Risk perception of vervet monkeys *Chlorocebus pygerythrus* to humans in urban and rural environments. Behav Processes 147:21-27. https://doi.org/10.1016/j.beproc.2017.12.011
Mucina L, Rutherford MC (2006) The Vegetation of South Africa Lesotho and Swaziland Strelitizia 19. South African National Biodiversity Institute, Pretoria
Murphy GE, Romanuk TN (2012) A meta-analysis of community response predictability to anthropogenic disturbances. Am Nat 180:316-327. https://www.jstor.org/stable/10.1086/666986
Naude VN, Smyth LK, Weideman EA et al. (2019) Using web-sourced photography to explore the diet of a declining African raptor the Martial Eagle (*Polemaetus bellicosus*). The Condor 121:1-9. https://doi.org/10.1093/condor/duy015
Patterson L, Kalle R, Downs CT (2017) A citizen science survey: perceptions and attitudes of urban residents towards vervet monkeys Urban Ecosyst 20:617-628. https://doi.org/10.1007/s11252-016-0619-0
Patterson L, Kalle R, Downs CT (2018) Factors affecting presence of vervet monkey troops in a suburban matrix in KwaZulu-Natal South Africa Landscape Urban Plan 169:220-228. https://doi.org/10.1016/j.landurbplan.2017.09.016

Patterson L, Kalle R, Downs CT (2019) Living in the suburbs: Space use by vervet monkeys (*Chlorocebus pygerythrus*) in an eco-estate South Africa. Afr J Ecol 57:539-551. https://doi.org/10.1111/aje.12629
Riley EP (2008) Ranging patterns and habitat use of Sulawesi Tonkean macaques (*Macaca tonkeana*) in a human-modified habitat. Am J Primatol 70:670-679. https://doi.org/10.1002/ajp.20543
Roy KE (2016) Seeing the wood for the trees: an evaluation of the Buffelsdraai Landfill Community Reforestation Project. Dissertation, University of KwaZulu-Natal
Saj TL (1998) The ecology and behavior of vervet monkeys in a human-modified environment. Dissertaion, University of Calgary
Saj T, Sicotte P, Paterson JD (1999) Influence of human food consumption on the time budget of vervets. Int J Primatol 20:977-994. https://doi.org/10.1023/A:1020886820759
Seoraj-Pillai N, Pillay N (2017) A meta-analysis of human-wildlife conflict: South African and global perspectives. Sustainability 9:1-21. https://doi.org/10.3390/su9010034
Seto KC, Parnell S, Elmqvist T (2013). A global outlook on urbanization. In: Elmqvist T, Frakias M, Goodness J et al. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Springer, Dordrecht, pp 1-12
Seyfarth RM (1980) The distribution of grooming and related behaviors among adult female vervet monkeys. Anim Behav 28:798-813. https://doi.org/10.1016/S0003-3472(80)80140-0
Seyfarth R, Cheney D (1990) The assessment by vervet monkeys of their own and another species' alarm calls. Anim Behav 40:754-764. https://doi.org/10.1016/S0003-3472(05)80704-3
Siljander M, Kuronen T, Johansson T et al. (2020) Primates on the farm-spatial patterns of human-wildlife conflict in forest-agricultural landscape mosaic in Taita Hills Kenya. Appl Geogr 117:1-13. https://doi.org/10.1016/j.apgeog.2020.102185
Sillero-Zubiri C, Switzer D (2001) Crop raiding primates: searching for alternative humane ways to resolve conflict with farmers in Africa. Wildlife Conservation Research Unit, Oxford University, Oxford
Skidmore AK, Franklin J, Dawson TP, Pilesjö P (2011) Geospatial tools address emerging issues in spatial ecology: a review and commentary on the Special Issue. Int J Geogr Inf Sci 25:337-365. https://doi.org/10.1080/13658816.2011.554296
Smithers RH (2012) Smithers Mammals of Southern Africa. Penguin Random House, South Africa
Snowdon CT (2020) Vervet monkey alarm calls: Setting the historical context. Anim Behav Cogn 7:87-94. https://doi.org/10.26451/abc.07.02.02.2020
Soulsbury CD, White PC (2016) Human-wildlife interactions in urban areas: a review of conflicts benefits and opportunities. Wildlife Res 42:541-553. https://doi.org/10.1071/WR14229
StatsSA (2011) Census 2011: Statistics South Africa South African Population Census 2011 https://wazimap co za/profiles/ward-59500066-ethekwini-ward-66-59500066/ Accessed 30 January 2020
Streicher JP, Ramesh T, Downs CT (2020) Home range and core area utilisation of three co-existing mongoose species: large grey water and white-tailed in the fragmented landscape of the KwaZulu-Natal Midlands South Africa. Mamm Biol 100:273-283. https://doi.org/10.1007/s42991-020-00028-8
Struhsaker TT (1967) Social structure among vervet monkeys (*Cercopithecus aethiops*) Behaviour 29:83-121
Strum SC (2010) The development of primate raiding: implications for management and conservation. Int J Primatol 31:133-156. https://doi.org/10.1007/s10764-009-9387-5

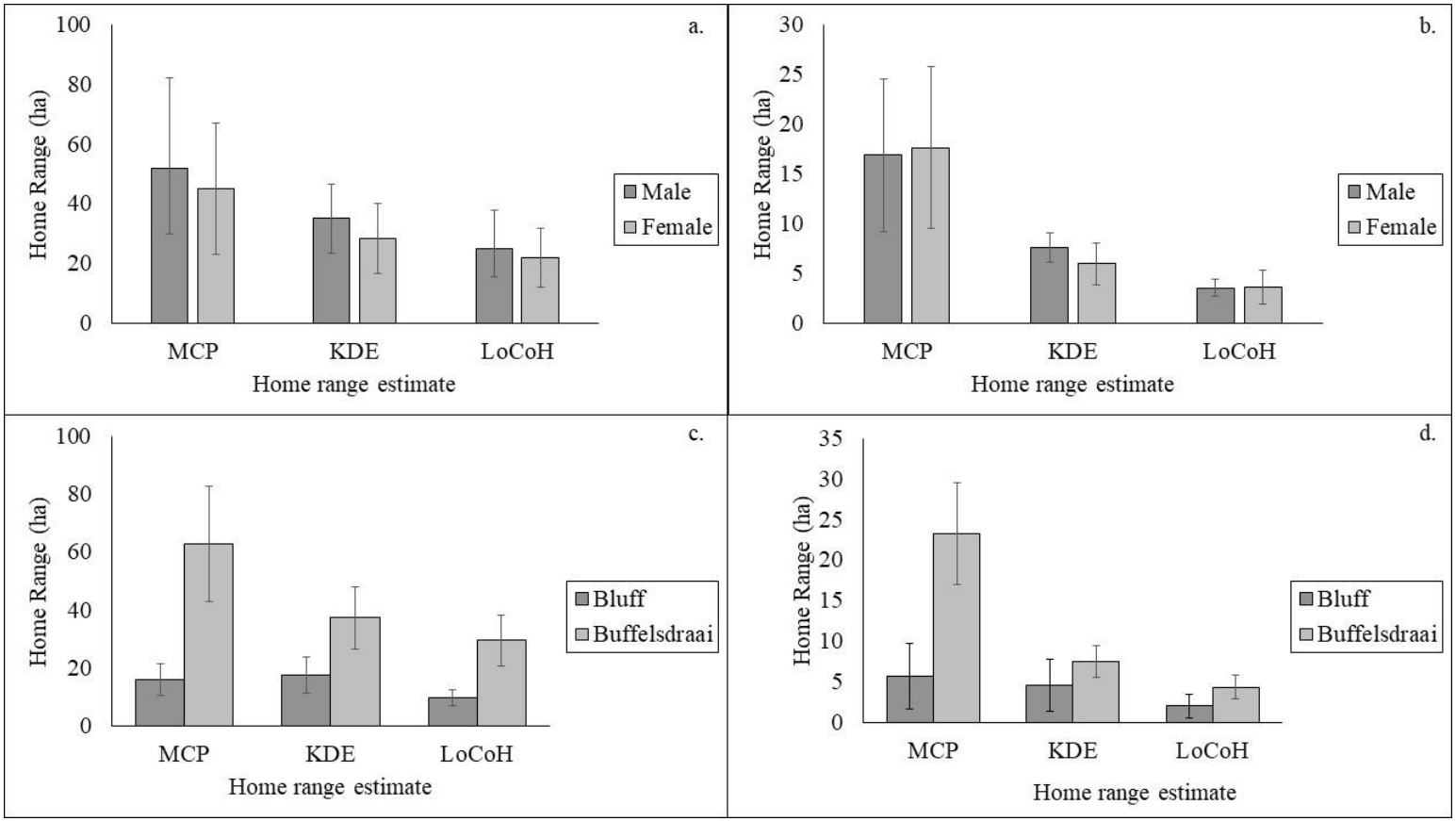
Swedell L (2012) Primate Sociality and Social Systems. Nature Education Knowledge 3:84
Teichroeb J A (2015a) Vervet monkeys use paths consistent with context-specific spatial movement heuristics Ecol Evol 5:4706-4716. https://doi.org/10.1002/ece3.1755
Teichroeb JA, White MMJ, Chapman CA (2015b) Vervet (*Chlorocebus pygerythrus*) intragroup spatial positioning: dominants trade-off predation risk for increased food acquisition. Int J Primatol 36:154-176. https://doi.org/10.1007/s10764-015-9818-4
Thatcher HR, Downs CT, Koyama NF (2019a) Positive and negative interactions with humans concurrently affect vervet monkey (*Chlorocebus pygerythrus*) ranging behavior. Int J Primatol 40:496-510. https://doi.org/10.1007/s10764-019-00099-6
Thatcher HR, Downs CT, Koyama NF (2019b) Anthropogenic influences on the time budgets of urban vervet monkeys. Landscape Urban Plan 181:38-44. https://doi.org/10.1016/j.landurbplan.2018.09.014
Thatcher HR, Downs CT, Koyama NF (2020) Understanding foraging flexibility in urban vervet monkeys *Chlorocebus pygerythrus* for the benefit of human-wildlife coexistence Urban Ecosyst 23:1349-1357. https://doi.org/10.1007/s11252-020-01014-1
Turner TR, Cramer JD, Nisbett A, Patrick Gray J (2016) A comparison of adult body size between captive and wild vervet monkeys (*Chlorocebus aethiops sabaeus*) on the island of St Kitts. Primates: J Primatol 57:211-220. https://doi.org/10.1007/s10329-015-0509-8
Turner TR, Schmitt CA, Cramer JD et al. (2018) Morphological variation in the genus *Chlorocebus*: Ecogeographic and anthropogenically mediated variation in body mass postcranial morphology and growth. Am J of Phys Anthropol 166:682-707. https://doi.org/10.1002/ajpa.23459
Turner T, Hill R, Coetzer WG, Patterson L (2016) A conservation assessment of Chlorocebus pygerythrus. In: Child MF, Roxburgh L, Do Linh San E, Raimondo D, Davies-Mostert HT (ed) The Red List of Mammals of South Africa Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa
United Nations Department of Economic and Social Affairs Population Division (2019) World Urbanization Prospects: The 2018 Revision (ST/ESA/SER A/420), New York: United Nations
Valiente-Banuet A, Aizen MA, Alcántara JM et al. (2015) Beyond species loss: the extinction of ecological interactions in a changing world. Funct Ecol 29:299-307. https://doi.org/10.1111/1365-2435.12356
van Beest FM, Rivrud IM, Loe LE, Milner JM, Mysterud A (2011) What determines variation in home range size across spatiotemporal scales in a large browsing herbivore? J Anim Ecol 80:771-785. https://doi.org/10.1111/j.1365-2656.2011.01829.x
Van Moorter B, Rolandsen CM Basille M, Gaillard JM (2016) Movement is the glue connecting home ranges and habitat selection. J Anim Ecol 85:21-31. https://doi.org/10.1111/1365-2656.12394
Villarreal-Barajas T, Martorell C (2009) Species-specific disturbance tolerance competition and positive interactions along an anthropogenic disturbance gradient. J Veg Sci 20:1027-1040. https://doi.org/10.1111/j.1654-1103.2009.01101.x
Walter WD, Fischer JW, Baruch-Mordo S, VerCauteren KC (2011) What is the proper method to delineate home range of an animal using today's advanced GPS telemetry systems: the initial step. In: Krejcar O, Modern Telemetry. InTech, Crotia
Walter, WD, Onorato, DP, Fischer, JW (2015). Is there a single best estimator? Selection of home range estimators using area-under-the-curve. Mov Ecol 3: 1-11. https://doi.org/10.1186/s40462-015-0039-4

Wiegand T, Revilla E, Moloney KA (2005) Effects of habitat loss and fragmentation on population dynamics. Conserv Biol 19:108-121. https://doi.org/10.1111/j.1523-1739.2005.00208.x
Willems EP, Barton RA, Hill RA (2009) Remotely sensed productivity regional home range selection and local range use by an omnivorous primate. Behav Ecol 20:985-992. https://doi.org/10.1093/beheco/arp087
Willems EP (2007) From space to species: integrating remotely sensed information on primary productivity into investigations and systems models of vervet monkey (Cercopithecus aethiops) socio ecology. Dissertation, Durham University
Wimberger K, Downs CT (2010) Annual intake trends of a large urban animal rehabilitation centre in South Africa: a case study. Anim Welfare 19:501-13.
Wimberger K, Downs CT, Boyes RS (2010) A survey of wildlife rehabilitation in South Africa: is there a need for improved management? Anim Welfare 19:481-499.
Worton BJ (1989) Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168. https://doi.org/10.2307/1938423
Zipperer WC, Wu J, Pouyat RV, Pickett STA (2000) The application of ecological principles to urban and urbanizing landscapes. Ecol Appl 10:685-688. https://doi.org/10.2307/2641038
Zungu MM, Maseko MS, Kalle R, Ramesh T, Downs CT (2020) Factors affecting the occupancy of forest mammals in an urban-forest mosaic in eThekwini Municipality Durban South Africa. Urban For Urban Gree 48:1265. https://doi.orgw/10.1016/j.ufug.2019.126562

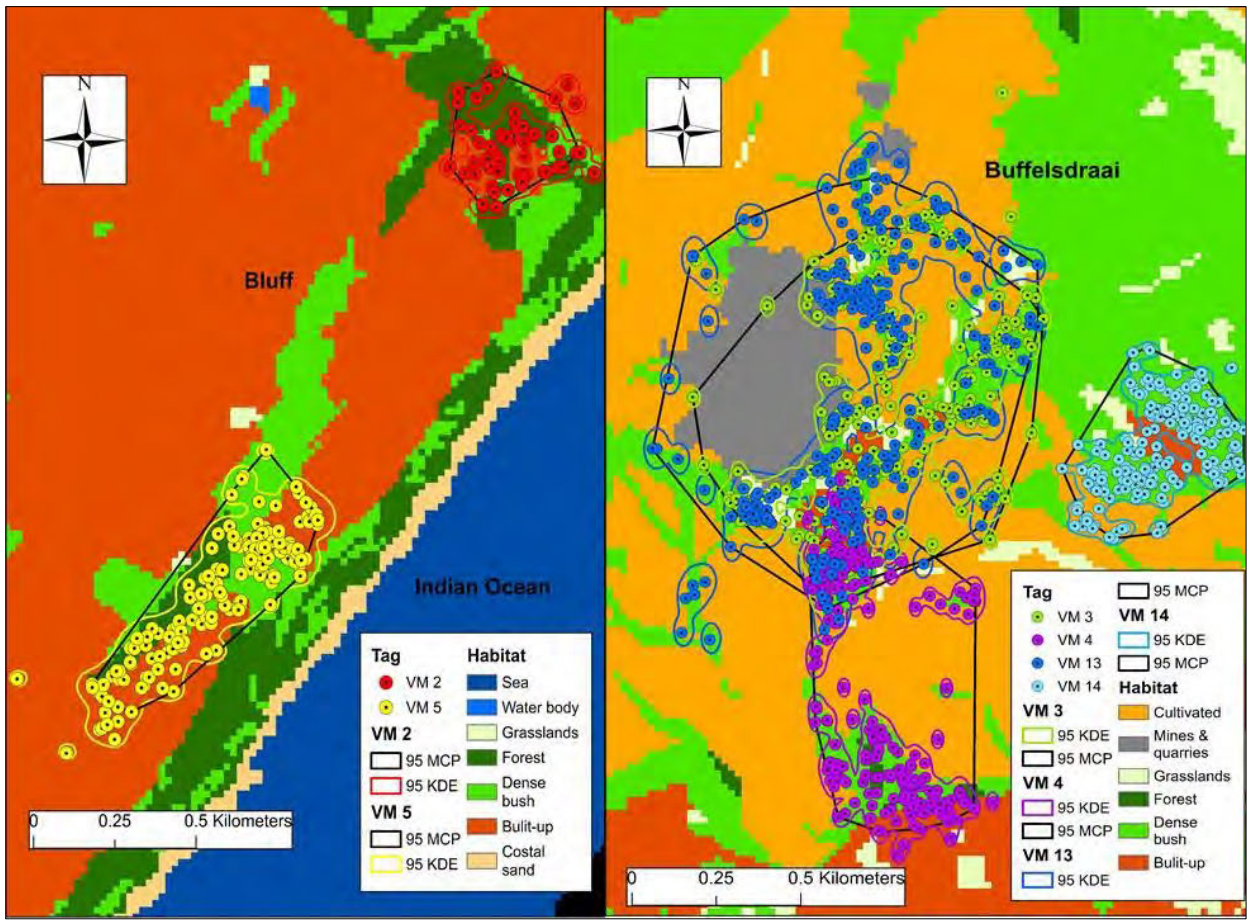
2.8 Supplementary information

Supplementary information Table S2.1. The home range sizes for 95% MCP estimate reported in previous literature for vervet monkeys in Africa compared with the present study.

Location	Species	Method	Home range sizes (ha)	References
Samara Private Game Reserve, Eastern Cape Province, South Africa	*Cercopithecus aethiops*	Minimum convex polygon (MCP) estimates of both the home range size (99% MCP) and each troop's core area (50% MCP), using an adaptive kernel with a bandwidth of 25 m	99% MCP: 63.7 –176.1 50% MCP: 7.42 –10.45	Pasternak et al., 2013
Simbithi Eco-Estate, KwaZulu-Natal, South Africa	*Chlorocebus pygerythrus*	Home range size of individuals and troops using both MCP and KDE methods in the *adehabitatHR*	95% MCP: 37 – 148 50% MCP: 12 – 32	Patterson et al., 2019
Simbithi Eco-Estate, KwaZulu-Natal, South Africa	*Chlorocebus pygerythrus*	Total home range area (95% isopleths) and core area (50% isopleths) and KDE using the *adehabitat*	95% MCP: 183 – 317 50% MCP: 27– 28	Thatcher et al., 2019
eThekwini Municipality, KwaZulu-Natal, South Africa	*Chlorocebus pygerythrus*	Maximum Convex Polygon (MCP), Kernel Density Estimator (KDE), and Local Convex Hull (LoCoH) used at the 95% and 50% levels	95% MCP: 10.67 – 108.37 50% MCP: 2.21 – 36.68 95% KDE: 11.35 – 62.88 50% KDE: 2.99 – 12.26 95% LoCoH: 7.06 – 49.86 50% LoCoH: 1.34 – 8.63	Present study



Supplementary information Fig. S2.1. Home range of vervet monkeys in the present study where a. shows the overall mean (± S.E.) home range estimates between sexes for vervet monkeys at the 95% level; b. the overall mean (± S.E.) home range estimates between sexes for vervet monkeys at the 50% level; c. the overall mean (± S.E.) home range estimates between locations for vervet monkeys at the 95% level and d. the overall mean (± S.E.) home range estimates between locations for vervet monkeys at the 50% level.



Supplementary information Fig. S2.2. Vervet monkey ($n = 6$) GPS fixes (dots) within 95% MCP and KDE boundary showing the main land-use types of two locations within the urban forest mosaic landscape in the eThekwini Municipality, KwaZulu-Natal, South Africa.

CHAPTER 3

Surviving the urban jungle - vervet monkeys facing human-wildlife conflict in South Africa

Kerushka R. Pillay and Colleen T. Downs*

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

Formatted for *XXXXX*

*** Corresponding Author:** Colleen T. Downs

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

Other Emails and ORCIDs:

K. Pillay Email: kerushka@gmail.com; ORCID: https://orcid.org/0000-0002-4018-783X

Running header: Vervet monkeys facing human-wildlife conflict

3.1 Abstract

Despite the common destructive effects of urbanisation on biodiversity assemblages, certain species thrive in urban environments. One mammalian species that has persisted in the urban-forest mosaic landscape is the vervet monkey (*Chlorocebus pygerythrus*). It is a common resident primate in Durban, eThekwini Municipality, KwaZulu-Natal Province, South Africa, with frequent contact with humans and domestic wildlife. As a result of their ability to exploit human-altered landscapes, human-vervet monkey conflict has intensified from a range of anthropogenic risks. Our study determined trends in the admission cases of vervet monkeys and assessed the main factors contributing to this to mitigate human-vervet monkey conflict. Our analyses were conducted on recorded admission data for vervet monkeys at a wildlife rehabilitation centre from 2011 to 2018. Members of the public (90.0%) mostly reported vervet cases, with admissions mostly recorded from the central district (46.8%) of the municipality. The number of admitted vervets increased significantly over the years and months, with a mean (± SE) of 127.3 ± 21.34 and 84.8 ± 5.4, respectively. Only 34.3% of vervets were alive at the end of the admission process from the 83.7% that were admitted alive at the rehabilitation centre. The high number of deaths resulted from anthropogenic activities, primarily motor vehicle strikes (30.8%) and domestic dog (*Canis lupus familiaris*) attacks (13.9%). We modelled survivability of vervets, and season (autumn), geographical location, age (adult, subadult, infant), and cause of admission (attack by dog, other and pet) were significant factors affecting survival after admission. We suggest that wildlife rehabilitation centres in priority areas use the results in education to improve human coexistence with vervet monkeys. The trends also serve as a foundation for human-vervet conflict resolution programmes. The advantages of publishing records from rehabilitation centres will

provide awareness of the complexity of this 'pest' species under anthropogenic influences in the urban mosaic landscape.

Keywords: *Chlorocebus pygerythrus*, human-wildlife conflict, rehabilitation centre, urbanisation, wildlife rescue

3.2 Introduction

Presently, 55% of the world's human population lives in urban areas, and this is expected to grow to 2.5 billion people by 2050 in the same area, with close to 90% of this increase taking place in Africa (UN, 2018). Urbanisation is a contributing factor to land-use change that threatens biodiversity in towns and cities as people migrate from rural to urban and suburban landscapes (Grimm et al., 2008; Nuissl and Siedentop, 2021). Urban sprawl and human expansion give rise to anthropogenic activities such as land transformation for infrastructure development, industrialisation, recreation, and agriculture, which generally negatively impact biodiversity and ecosystem functioning (Hunter, 2007; Schwarz et al., 2017; Festus et al., 2020). Despite people aggregating in cities and moving away from rural areas, this potentially opens up opportunities for conservation in the rural areas, so overall, it remains to be seen whether it is a net benefit for conservation. Presently, the major threat to biodiversity loss is the transformation of natural areas as exhibited in the metropolitan of Durban, eThekwini Municipality, KwaZulu-Natal Province, South Africa (EPCPD, 2020). With a population of ~3.9 million people, spanning an area of ~2,555 km^2 (COGTA, 2020), the conversion of natural land to accommodate the rapid expansion of urbanisation has led to an overlap of humans and wildlife in this urban-forest landscape mosaic, ultimately leading to various human-wildlife conflicts in the municipality (Zungu et al., 2020; McPherson et al., 2021).

Historically humans and wildlife have coexisted; however, the magnitude of human-wildlife interactions has risen recently (Peterson et al., 2010; Manfredo, 2015; Anand and Radhakrishna, 2017; Parathian et al., 2018). Urban wildlife differs from other wildlife by the increased level of interaction with people and human-modified environments; and can be displayed as either positive, neutral, or negative interactions (Soulsbury and White, 2015; Mormile and Hill, 2017; Soulsbury and White, 2019). Previous research examined negative associations around human-wildlife conflict (HWC) and documented direct factors implicating wildlife through physical attacks, property damage and disease transmission (Distefano, 2005; LaBarge et al., 2020; Siljander et al., 2020). HWC occurs in a heterogeneous mosaic landscape that contains a large network of buildings, manicured gardens, linear infrastructure (e.g., walls, roads, bridges), and rivers, interconnecting remanent patches of natural forests and green belts (Werner, 2011; McPherson et al., 2021). The frequency of interactions between humans, infrastructure and wildlife occurring because of encroachment increases the likelihood of conflict events (Soulsbury and White, 2015). Human-induced environmental changes typically act as a non-random filter allowing only the most adaptable species to survive under modified conditions, known as biotic homogenisation (Smart et al., 2006). Certain species, often generalists, show behavioural plasticity and persist in transformed urban landscape mosaics (Downs et al., 2021). Under intensive human activity, mammalian species that use and exploit sources of food and shelter while attaining abundance and biomass in their population are known as urban adapters and can be described as species that can survive equally well in the urban and natural environment (McKinney, 2002, 2006; Fischer et al., 2015).

It is important to understand how wildlife populations and human communities respond to urbanisation and the associated increased human interactions to deal with potential HWC. Despite

the commensal relationship with urban development, primates are responsible for some of the most intense HWC worldwide (Hill and Webber, 2010; Dickman, 2012; Seoraj-Pillai and Pillay, 2017). In developing countries like South Africa, HWC is a concern for food insecurity and economic losses as the conflict is primarily associated with crop-raiding events by primates (Sillero-Zubiri and Switzer, 2001; Hill, 2005; Warren, 2009; Findlay, 2016). Following the conflict arising through direct or indirect human negative interactions, many injured primates are admitted to rehabilitation centres (Grobler et al., 2006; Wimberger and Downs, 2010; Guy, 2013; Guy et al., 2013).

Primate species like the vervet monkey (*Chlorocebus pygerythrus*, hereafter vervet) are highly adaptable and exhibit urban adaptations as they have opportunistically exploit resources in anthropogenic landscape mosaic habitats (Patterson et al., 2018; Thatcher et al., 2019a). This habitat generalist has adapted and shown persistence in fragmented and cultivated landscapes, including the urban environment, maintaining an omnivorous diet based on the seasonal availability of plants, berries, shoots, fruits, and invertebrates (Butynski and De Jong, 2019). The vervet is a semi-arboreal primate occurring in all nine provinces of South Africa (Turner et al., 2016). Often widespread and abundant in its present geographic distribution range, vervets are tolerant to a wide variety of niches that include riverine woodland, open savannah, forest-grassland mosaics, and coastal scrub forest, but are limited to available drinking water and sleeping sites (Skinner and Chimimba, 2005; Turner et al., 2016).

Classified as “Least Concern” on the International Union for Conservation of Nature Red List, the present population trend for vervets is decreasing in Africa (Butynski and De Jong, 2019). In South Africa, vervets are protected by law. However, according to the Nature Conservation Ordinance 15 of 1974, KwaZulu-Natal Province, vervets can be legally kept in captivity subject

to permits for research, zoos, circuses, and museums but not as pets. Although there are no official data on population counts of vervets within the municipality, vervets are relatively common and highly visible (Patterson et al., 2017, 2018). So, it may seem that the population is increasing but more so that they are observed and interacting more regularly and directly with people in urban and suburban areas.

Generally, people have a low tolerance for vervets and consider them pests upon their entering gardens and homes searching for food, inadvertently causing property damage, and bringing about conflict (Saj, 1998). Apart from raiding events, vervets rummage through garbage and waste tips, further escalating animosity towards the species (Patterson et al., 2017). Whilst humans scare off vervets, occasionally attacks on domestic pets, children, or women ensue, and this further causes the discourse of blame toward vervets rooted in anger and frustration (pers. comm.). Additionally, vervets are considered vermin by farmers because of their raiding nature on crops grown for agricultural or subsistence farming (Naughton-Treves et al., 1998; Hill, 2005; Loudon et al., 2014; Cancelliere et al., 2018; Findlay and Hill, 2020). In addition, the lack of natural predators in urban areas such as pythons (*Python* spp.), leopards (*Panthera pardus*) and raptors (McPherson et al., 2016; Isbell and Etting, 2017) enable unconstrained movement of vervets in human-modified landscapes (Mikula et al., 2018; Thatcher et al., 2019a,b; LaBarge et al., 2020).

Coupled with these conflict events, vervets are prone to persecution by humans because of their nuisance foraging habits resulting in their high admissions at several rehabilitation facilities centres across South Africa (Wimberger and Downs, 2010; Guy and Curnoe, 2013; Thatcher et al., 2019b). Repeated incidents include domestic pet attacks, shootings, car accidents and poisonings (Wimberger and Downs, 2010; Guy et al., 2011; Guy and Curnoe, 2013). The

possibility of vervets surviving injuries by anthropogenic encounters in urban and suburban areas has been poorly documented. Previous studies have reported vervet admittance data for a specialist vervet monkey rehabilitation centre (Healy and Nijman, 2014) and account for some conflict because of anthropogenic threats (Wimberger and Downs, 2010). However, our study is the first long-term, continuous dataset, from 2011 to 2018, assessment of vervets to a wildlife rehabilitation centre that caters for all species of wildlife in one of South Africa's largest metropolitan cities, Durban. Our study aimed to determine the trends and key factors contributing to HWC from admission records of vervets to suggest viable mitigation measures. Our study highlights the plight and risk that this primate species face in the urban-forest mosaic landscape and allows authorities to take an overview of circumspection to alleviate HWC. Furthermore, we highlight the causes of admission and reveal areas of concern for HWC. We also highlight the anthropogenic threats and outcome of survivability by anthropogenic encounters of vervets admitted. We predicted temporal and seasonal variations in trend data because of anthropogenic factors.

3.3 Materials and methods

3.3.1 CROW – Centre for Rehabilitation of Wildlife

The Centre for Rehabilitation of Wildlife is a registered non-profit organisation dedicated to the rescue, rehabilitation and release of indigenous wildlife and is the only registered wildlife rehabilitation centre in Durban, eThekwini Municipality, South Africa. Founded in 1977, CROW is situated in the suburb of Yellowwood Park and annually assists over three thousand orphaned, injured, and displaced wildlife from the municipality (Wimberger and Downs, 2010; unpublished data). As part of the International Wildlife Rehabilitation Council, CROW prioritises rehabilitation and release as its main conservation efforts while promoting conservation through education

initiatives and active participation by the community. Ezemvelo KZN Wildlife permitted CROW to keep 150 vervet monkeys at its on-site rehabilitation facility in large outdoor enclosures, mostly used for recovering, rehabilitating or unreleasable vervets (CROW management pers. comm.). Vervets were either reported to CROW or brought in by the public. CROW would go out on rescues to assist incapacitated, or injured vervets reported. This project was conducted as part of an MOU with the University of KwaZulu-Natal (UKZN) and CROW.

3.3.2 Data acquisition

We obtained data from hard copy files that documented comprehensive information recorded by the staff employed at CROW for the rescue and rehabilitation of vervets admitted to CROW from 01 January 2011 to 31 December 2018. Admission records included the date, admission source, location, history, type of rescue, alive on admission, sex, age, cause of admission and the final outcome. All information was manually entered into Microsoft Excel (Version 2111), cleaned, and categorised for data interpretation to identify trends. Graphical data representations were prepared using the most significant findings and displayed.

We classified the data into categories for statistical analyses to determine trends in the number of vervet admission cases. Years were grouped annually (2011-2018), and months by austral seasons, Spring: September-November; Summer: December-February; Autumn: March-May; Winter: June-August. The admission sources of vervets were grouped into two main categories: a member of the public or another wildlife rehabilitation centre. Geographical source locations of vervets were grouped into the following districts of the municipality: Central, North, South, Inner West, Outer West and other, which included all admissions from outside the boundary of the municipality and unknown/not recorded locations. Types of vervet rescues were grouped as

'rescue and callouts or 'drop-offs'. Vervets alive on admission were classified as yes or no based on the historical context of the case at the beginning of the admission to the centre. The sexes of vervets admitted were listed as male, female, undetermined, or not recorded. The age of vervets admitted was classified into age classes which were determined by their size and dental form by CROW and kept as-is for this study: infant: 0-6 months; juvenile: 6 months - 1.5 years old; subadult: 1.5 years – 2-3 years old; adult: + 4 years old; undetermined – unidentifiable by CROW because of severe body injuries. We identified nine main causes of admission and listed them as per their categories for admission, with some pooled (e.g., 'sold as pet' and 'kept as pet', Supplementary information Table S3.1). The main causes of admission were identified as 1. attacked by a domestic dog (*Canis lupus familiaris*), 2. attacked by another monkey, 3. malicious, 4. motor vehicle strike, 5. orphaned, 6. other, 7. pet, 8. shot and 9. unknown. The final outcomes of vervet admissions were classified as died, euthanised, housed in captivity or released. The survivability of each vervet admitted was categorised as dead or alive at the end of the admission process based on its final outcome.

3.3.3 Statistical analyses

We analysed the data using IBM SPSS Statistics 27.0 (IBM, Armonk, USA). Chi-square goodness-of-fit tests were performed to determine if any relationship exists between the categorical data for admission source, district of the municipality, type of rescue, alive on admission, cause of admission and final outcome. We also determined the overall relationship of vervet admissions compared between the sexes and age classes. Linear regression was used to determine the annual trends of admission cases, and Chi-square goodness-of-fit tests were computed for monthly and seasonal trends. Pearson chi-square test of independence was used for seasonal comparisons of

admissions in terms of sex, age class, district of the municipality and outcome of admission. To determine the impacts and seasonal trends in HWC, we compared causes of admission between the seasons. The values were presented as means (± SE) where applicable, and significance was set at $p < 0.05$ for all tests.

3.3.4 Survivability

To investigate potential differences in survivability, we used a binary logistic regression to determine between independent variables for the outcome of vervets surviving after being admitted to the rehabilitation centre (Maphalala et al., 2021). Binary classification of survivability was used as the dependent variable for the model classified as 'dead' (not alive: euthanised or dead) was '0' and 'alive' (survived: housed in captivity and released) represented '1' in the statistical model; to model the likelihood of survival. At first, the predictor variables were assessed separately with the outcome variable and selected for inclusion of the model if $P < 0.05$. Six predictor variables were included in the final model: season, location within the municipality, sex, age class and cause of admission (Supplementary information Table S3.2); and the effects of these independent variables on survivability as a dependent variable were analysed. Admission cases with information 'not recorded' and 'unknown' information was removed from the model (Table 3.1). To calculate the odds ratio for each category within the predictor variable, the first category was selected as a reference to which the remaining variables were compared. The effect sizes were expressed as odds ratios (the ratio of P [alive] to P [dead]), where odds ratios of less than one indicated that vervets were more likely to die after admission than to survive (Molony et al., 2007). To determine a good model fit model, Hosmer-Lemeshow, Cox and Snell, and Nagelkerke R square statistics

were considered. The overall proportions of causes of vervet admission were grouped by survivability.

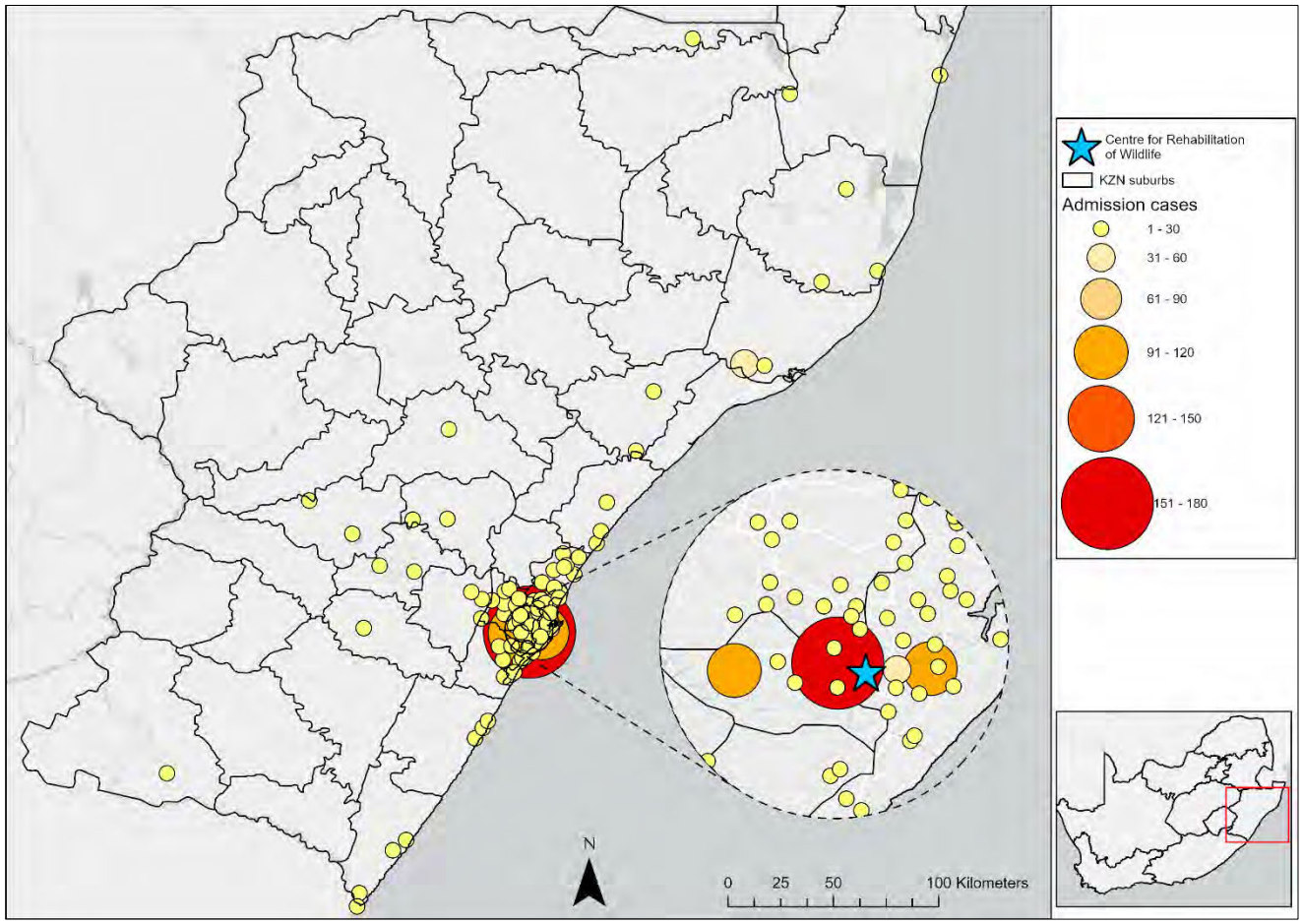


Fig. 3.1. Vervet monkey admission cases (N = 1018) located in the nearest suburb and reported to an urban wildlife rehabilitation centre in KwaZulu-Natal, South Africa between 2011 and 2018 in the present study.

3.4 Results

3.4.1 Vervet admissions

Between January 2011 and December 2018, a total of 1018 vervet monkeys were admitted to the wildlife rehabilitation centre, CROW, in eThekwini Municipality (Fig. 3.1). Vervet admissions were significantly reported more by members of public (90.0%, $N = 916$) than another wildlife rehabilitation centre (10.0%, $N = 102$) (χ^2 (1) = 650.880, $p < 0.05$, Table 3.1). The distribution of vervet admissions from districts in eThekwini Municipality differed significantly by geographical location with most cases admitted from the Central (46.8% $N = 476$), Inner West (26.6%, $N = 271$) and other districts (15.5%, $N = 158$), followed by relatively low admissions from South (4.3%, $N = 4$), North (3.6%, $N = 37$) and Outer West district (3.1%, $N = 32$) (χ^2 (5) = 922.923, $p < 0.05$), Fig. 3.1, Table 3.1). There were far more rescues and callouts (74.6%, $N = 759$) than drop-offs (25.4%, $N = 259$) of vervet admissions. On arrival of admission, vervets differed with the majority arriving alive (83.7%, $N = 848$) rather than dead (16.7%, $N = 170$) (Table 3.1).

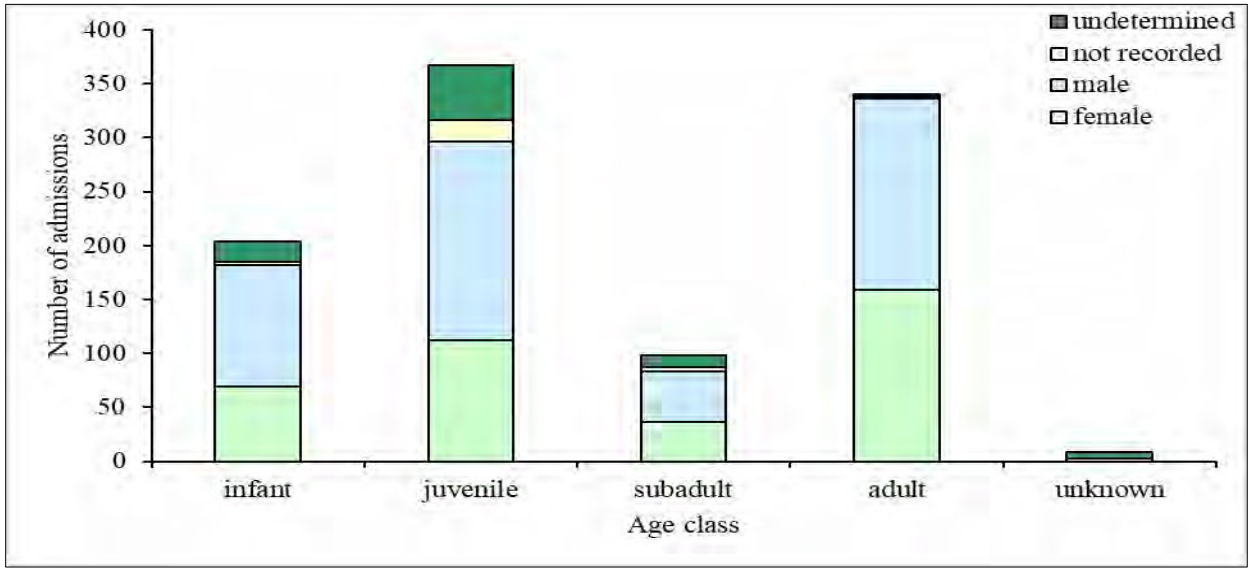


Fig. 3.2. The number of admissions of vervet monkey age classes grouped by sexes reported to an urban wildlife rehabilitation centre between 2011 and 2018 in the present study.

Table 3.1. Summary of demographic information of vervet monkey admissions to CROW from 2011 to 2018.

Variable	Category	N	%
Admission source	Another WRC	102	10.0
	MOP	916	90.0
Municipality district	Central	476	46.8
	Inner west	271	26.6
	North	37	3.6
	Other	158	15.5
	Outer west	32	3.1
	South	44	4.3
Type of rescue	Rescue/callouts	259	25.4
	Drop-off	759	74.6
Alive on admission	No	170	16.7
	Yes	848	83.3
Sex	Female	376	36.9
	Male	521	51.2
	Not recorded	32	3.1
	Undetermined	89	8.7
Age	Adult	340	33.4
	Infant	204	20.0
	Juvenile	367	36.1
	Subadult	98	9.6
	Unknown	9	0.9
Cause f Admission (COA)	MVS	313	30.8
	Unknown	217	21.3
	ABD	141	13.9
	Orphaned	140	13.8
	Other	47	4.6
	Pet	42	4.1
	Malicious	41	4.0
	ABM	39	3.8
	Shot	38	3.7
Final outcome	Captivity	278	27.3
	Died	243	23.9
	Euthanised	484	47.5
	Released	13	1.3

*** Abbreviations:**
WRC – Wildlife Rehabilitation Centre
MOP – Member of Public
MVS – Motor Vehicle Strike
ABD – Attacked by Dog
ABM – Attacked by Monkey

The sexes and age classes of vervet admissions are summarised in Table 3.1. Overall, more male (51.2%, $N = 521$) than female (36.9%, $N = 376$) vervets were admitted to the centre. Juveniles (36.1%, $N = 367$) were the largest age class admitted followed by adults (33.4%, $N = 340$), infants (20.0%, $N = 204$), subadults (9.6%, $N = 98$ and unknown age (0.9%, $N = 9$). There were significant differences between the sexes and age classes of vervet admissions (χ^2 (1) = 245.580, $p < 0.05$, Fig. 3.2, Supplementary information Table S3.3). The final outcome of vervets admitted differed significantly with most being euthanised (47.5%, $N = 484$), followed by housed in captivity (27.3%, $N = 278$), died (23.9%, $N = 243$) and released (1.3%, $N = 13$) (χ^2 (3) = 438.809, $p < 0.05$), Table 3.1).

3.4.2 Trends in admissions

The number of vervets admitted ($N = 1018$) increased significantly annually during the study period (F (1,6) = 56.233; $p < 0.05$, $R^2 = 0.904$, Fig. 3.3, Supplementary information Table S3.4), with an annual mean intake rate of 127.3 ± 21.34 admissions per annum. We observed the highest increase change of 82% of admission cases in the year 2015. Total monthly admission cases were significantly different (χ^2 (11) = 44.790, $p < 0.05$), with mean monthly admission cases of 84.8 ± 5.37, peaking in the months of November and December and then dropping in January and February (Fig. 3.4, Supplementary information Table S3.4).

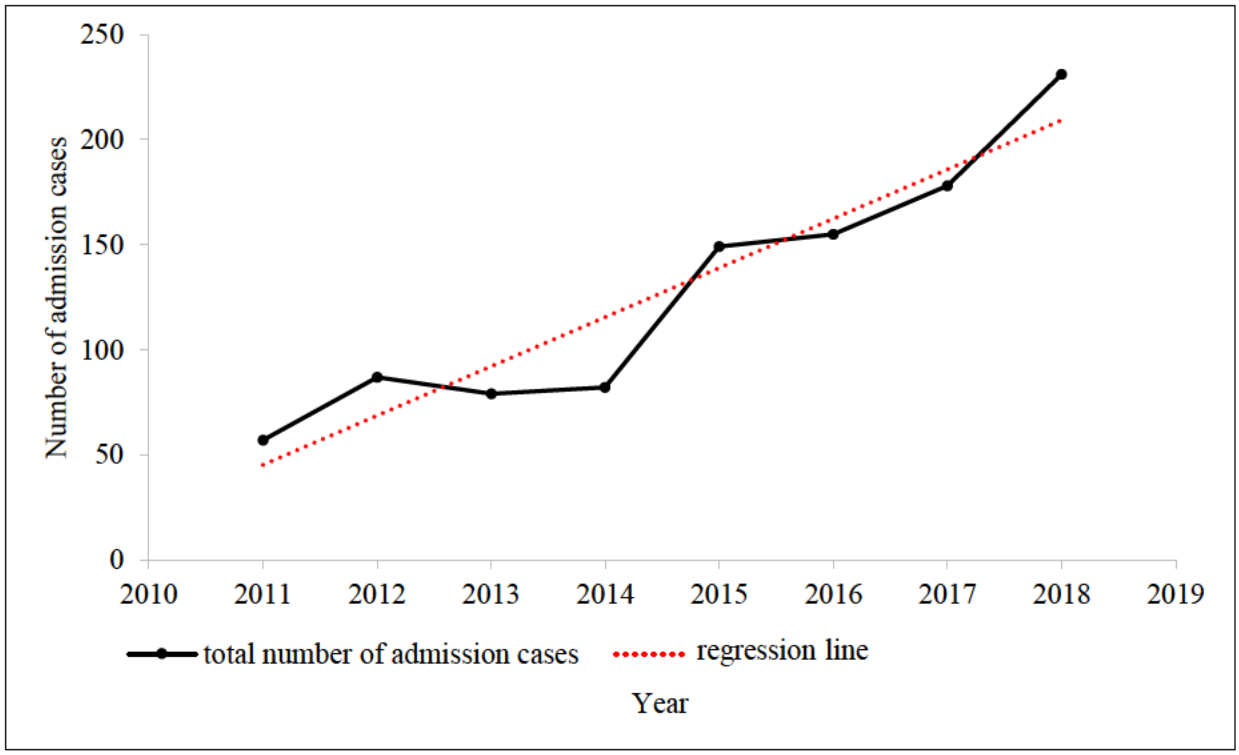


Fig. 3.3. Annual total number of admissions of vervet monkeys reported to an urban wildlife rehabilitation centre between 2011 and 2018.

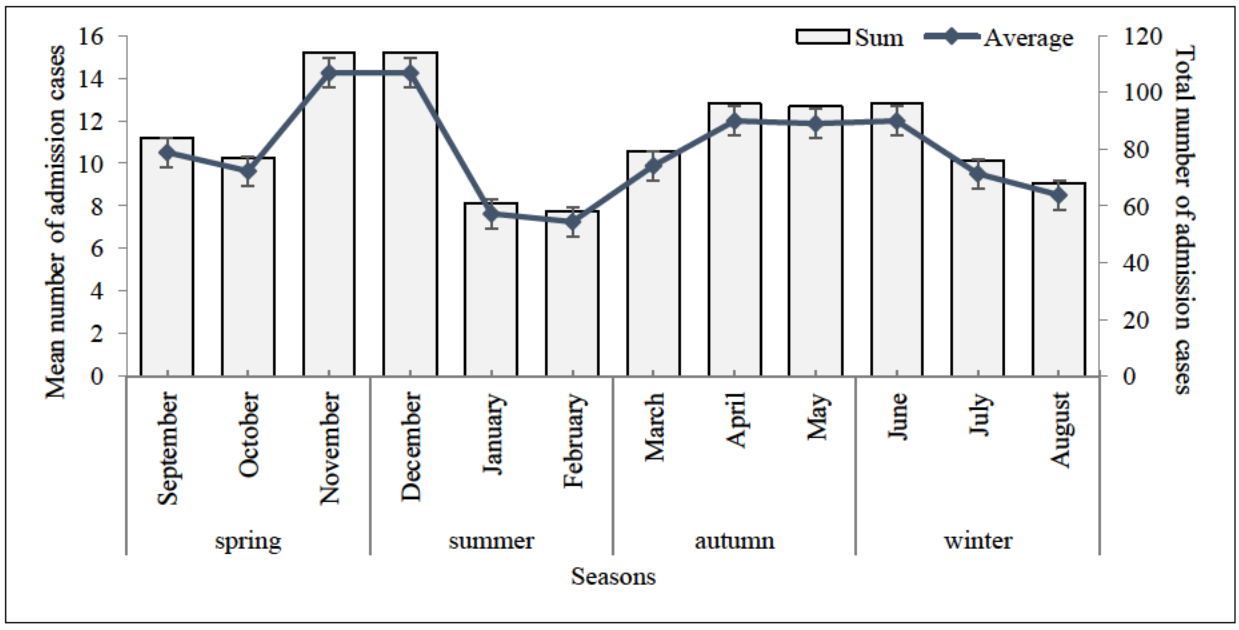


Fig. 3.4. Mean (±SE) and the total number of admissions of vervet monkeys reported monthly and seasonally to an urban wildlife rehabilitation centre between 2011 and 2018.

We observed seasonal admission trends in the admittance of vervets: spring [27.0%, N = 275], summer [26.5%, N = 270], autumn [23.6%, N = 240], winter [22.9%, N = 233], Supplementary information Table S3.4, Fig. 3.4). Although the number of admissions did not differ between seasons (χ^2 (3) = 5.238, p = 0.155, Fig. 3.4, Supplementary information Table S3.4), seasons did have a significant effect on the sex, age class, district of the municipality and final outcome of vervet admission cases (Fig. 3.5, Supplementary information Table S3.5). The number of admissions for seasons compared with age classes, sexes, district of the municipality, and final outcome are summarised (Fig. 3.5, Supplementary information Table S3.6). Male vervets were admitted mostly in autumn (53.0%, N = 143) than spring (44.4%, N = 122), whereas most females were admitted mostly in spring (45.8%, N = 126) than winter (32.5%, N = 78). In comparison, juvenile vervet admittance was highest in winter (52.1%, N = 125) and autumn (40.4%, N = 109) and lowest in summer (22.3%, N = 52). In contrast, infant vervet admittance was highest in summer (36.5%, N = 85) and spring (30.2% N = 83) and lowest in winter (2.9%, N = 7). Adult vervet admittance had the most cases in autumn (36.3%, N = 98) and spring (33.1%, N = 91), while subadult vervet admittance was low in all seasons. A substantial number of juveniles could not be sexed because of extreme injuries to the body.

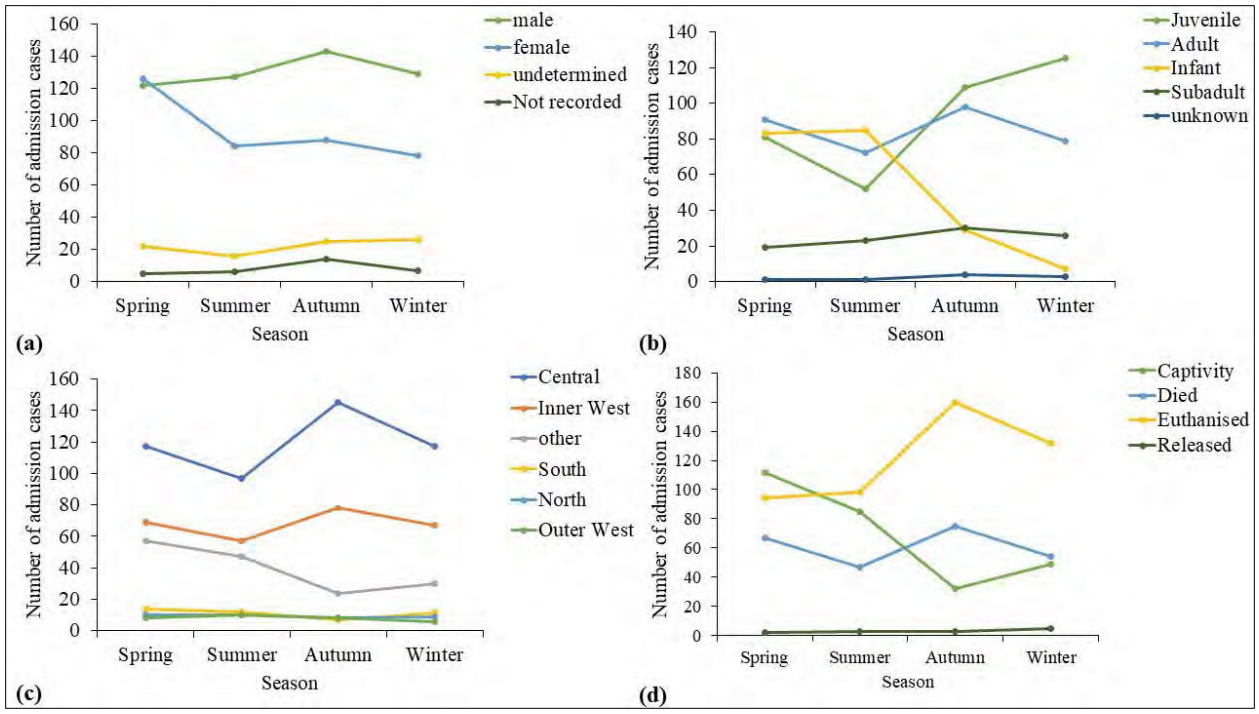


Fig. 3.5. Seasonal differences in admissions of vervet monkeys to an urban wildlife rehabilitation centre for (a) sex, (b) age class, (c) district of the municipality and (d) final outcome reported between 2011 and 2018.

The highest reported admission cases came from the Central district of the municipality during autumn (53.7%, N = 145), followed by the Inner West (28.9%, N = 78); however, other districts typically had low admission cases in autumn and their highest admission cases in spring (20.2%, N = 57). There were relatively few admissions throughout the year from the municipality's South, North, and Outer West districts. The final outcome for the season autumn had the highest cases of euthanasia (59.3%, N = 160) and deaths (27.7%, N = 75), whereas spring had the highest number of vervets housed in captivity (40.7%, N = 112). Although there were relatively few releases across the seasons (1.3%, N = 13), most releases took place in the winter (2.1%, N = 5).

3.4.3 Causes of admission

The most common cause of vervet admissions was motor vehicle strikes accounting for 30.8%, *N* = 313 admission cases, followed by unknown (21.3%, *N* = 217), attack by dog (13.9%, *N* = 141), orphaned (13.8%, *N* = 140), other (4.6%, *N* = 47), pet (4.1%, *N* = 42), malicious (4.0%, *N* = 41), attacked by another monkey (3.8%, *N* = 39) and shot (3.7, *N* = 38) (Fig. 3.6, Table 3.1). There were significant differences between the different causes of admission (χ^2 (8) = 689.684, $p < 0.05$).

Consistent with the overall increase in vervet admissions over time, admissions because of each cause of vervet admission increased annually over the study period (2011-2018, χ^2 (56) = 93.725, $p < 0.05$, Supplementary information Fig. S3.2a); monthly (χ^2 (24) = 160.939, $p < 0.05$, Supplementary information Fig. S3.2b) and as well as seasonally (Fig. 3.7, Supplementary information Table S3.6). The cause of vervet admissions was highest for motor vehicle strikes, attack by dog, malicious and attacked by another monkey in autumn. In contrast, orphaned, other and pet were highest in spring. Cause of vervet admissions for shot, and unknown were highest in winter (Supplementary information Table S3.6). Motor vehicle strikes were highest in autumn (37.4%, *N* = 117) and lowest in summer (21.7%, *N* = 68). Orphaned vervets were highest in spring (47.1%, *N* = 66) and summer (44.3%, *N* = 62) and extremely low in autumn and winter (4.3%, *N* = 6), respectively (Fig. 3.7, Supplementary information Table S3.6).

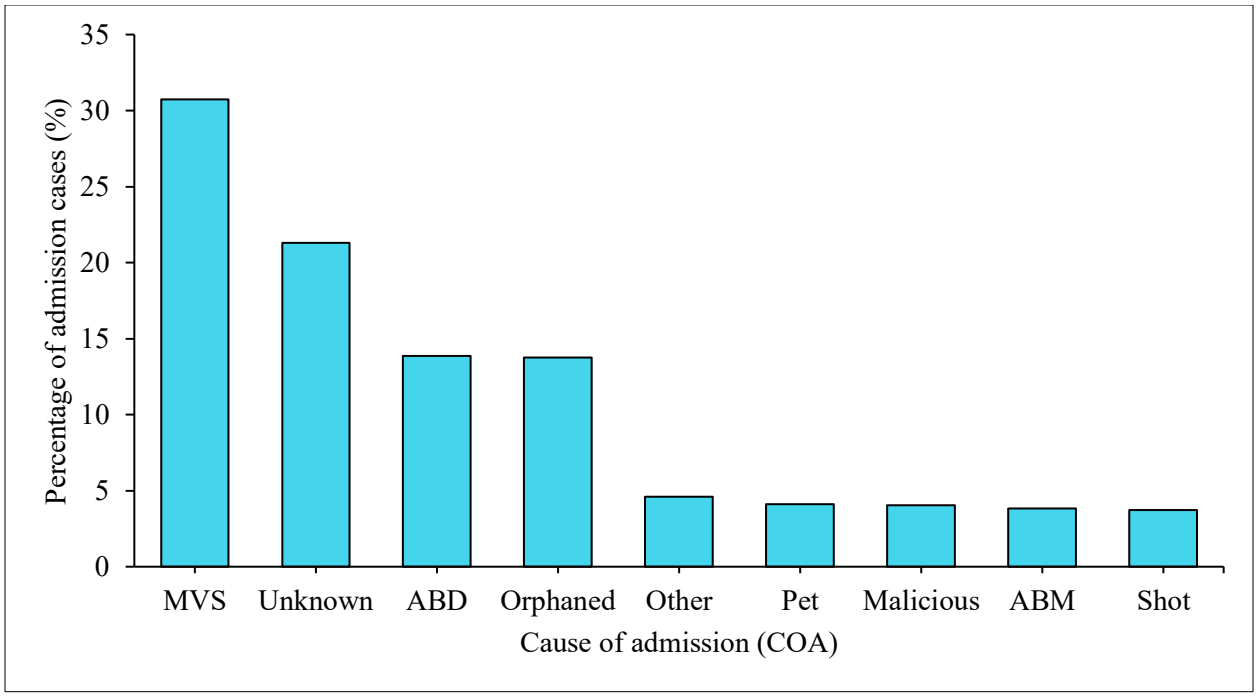


Fig. 3.6. Percentage of the cause of admissions of vervet monkeys reported to an urban wildlife rehabilitation centre between 2011 and 2018.

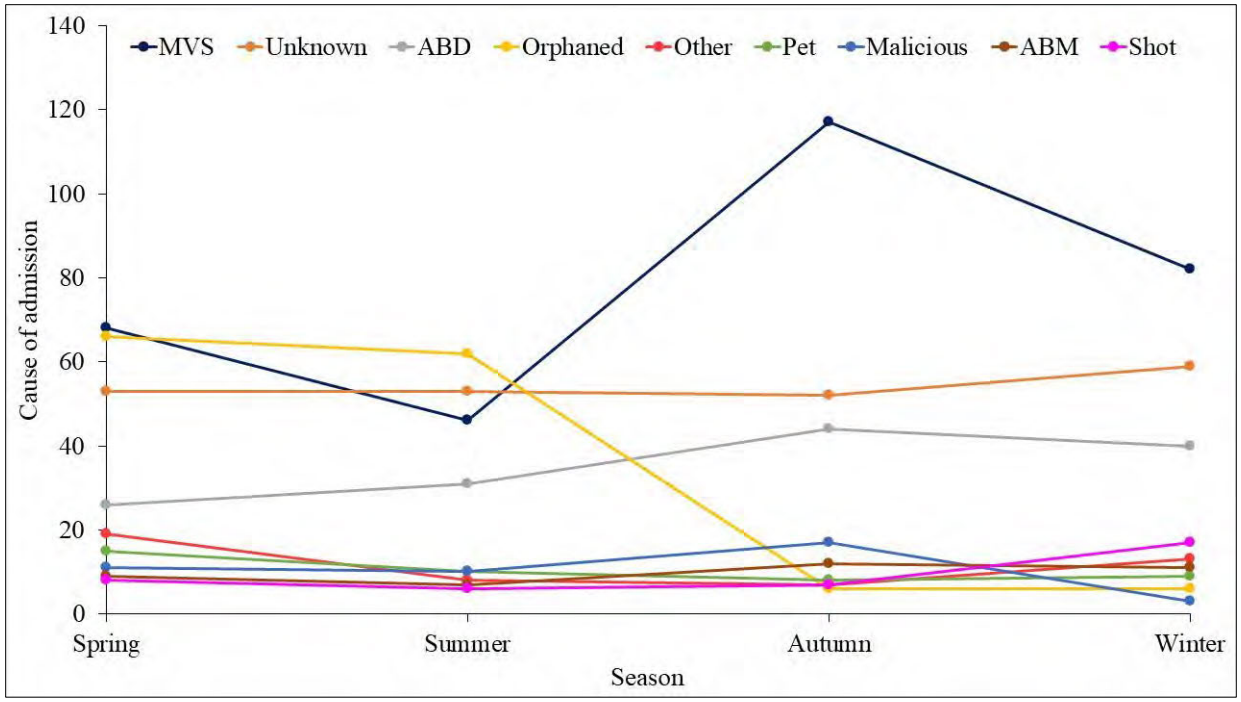


Fig. 3.7. Seasonal differences of admissions of vervet monkeys showing the cause of admissions reported to an urban wildlife rehabilitation centre between 2011 and 2018.

3.4.4 Survivability of admission

We conducted a binary logistic regression to assess the effect of season, sex, age class, geographical location in the municipality and cause of vervet admission on the likelihood of survivability of a vervet. After removing information that was labelled 'not recorded' from the large dataset, 997 records were used in the analyses. There was no significant difference between the fitted model with each of the variables and the data (Wald = 160.303, df = 1, p = 0.410 for all models), suggesting a good model fit. The overall accuracy of the model was 85.5%, and the final model correctly predicted 95.7% of vervets died and 60.6% were alive after admission. The overall model was statistically significant compared with the null model ($\chi2$ (18) = 431.614, $p < 0.05$), explained 51% of the variation of survival (Nagelkerke R2) and correctly predicted 85.5% of cases. Season ($\chi2$ = 17.004, df = 3, $p < 0.001$), age ($\chi2$ = 32.837, df = 3, $p < 0.001$), location in the municipality ($\chi2$ = 18.239, df = 2, $p < 0.001$), and cause of admission ($\chi2$ =85.439, df = 8, $p < 0.001$) were significant predictors of the outcome of survivability, although sex ($\chi2$ = 3.988, df = 3, p = 0.136) was not a significant predictor of survivability. The odds of surviving during the seasons increased in winter at 0.794 and summer at 0.725 times compared with spring. Juvenile age class were 0.629 times more like to survive than infants. The unknown locations of the municipality of reported admissions were 0.41 times more likely to survive when compared with cases located out of the municipality. For the cause of admission, the odds of survivability were highest for vervets admitted as pets by 21.5 times, followed by 9.063 times for vervets attacked by dogs, 2.403 times for 'other' causes and 1.433 times for being shot when compared with those admitted because of motor vehicle strikes (Table 3.2, Fig. 3.8). Of the total of 83% of vervets were alive at the centre on admission, only 34.3% were alive at the end of the admission process.

Table 3.2. Binary logistic regression models (0 = "dead" vs 1 = "alive") for vervets admitted to an urban wildlife rehabilitation centre in KZN, SA, between 2011 and 2018. (SE = Standard error, df = degrees of freedom, COA = cause of admission, * are reference categories for each variable).

Predictor variables	*B*	SE	Wald χ^2	*df*	*p* value	Odds ratio	95% CI for Odds Ratio	
							Lower	Upper
*Season (spring)			17	3	**0.001**			
Season (summer)	-0.321	0.262	1.504	1	0.22	0.725	0.434	1.212
Season (autumn)	-1.136	0.282	16.16	1	**0**	0.321	0.185	0.559
Season (winter)	-0.231	0.258	0.801	1	0.371	0.794	0.479	1.316
*Sex (male)			3.988	2	0.136			
Sex (female)	-0.386	0.207	3.477	1	0.062	0.68	0.453	1.02
Sex (undetermined)	-0.372	0.336	1.225	1	0.268	0.69	0.357	1.331
*Age (infant)			32.84	3	**0**			
Age (juvenile)	-0.463	0.29	2.554	1	0.11	0.629	0.357	1.111
Age (subadult)	-1.154	0.408	7.979	1	**0.005**	0.315	0.142	0.702
Age (adult)	-1.711	0.341	25.18	1	**0**	0.181	0.093	0.353
*Out the EM			18.29	2	**0**			
In the EM	-1.284	0.303	17.94	1	**0**	0.277	0.153	0.502
Unknown location	-0.893	0.531	2.827	1	0.093	0.41	0.145	1.159
*COA (MVS)			85.49	8	**0**			
COA (unknown)	-0.17	0.265	0.409	1	0.523	0.844	0.502	1.42
COA (ABD)	2.204	0.36	37.51	1	**0**	9.063	4.476	18.348
COA (orphaned)	-0.358	0.34	1.107	1	0.293	0.699	0.359	1.362
COA (other)	0.877	0.38	5.313	1	**0.021**	2.403	1.14	5.066
COA (pet)	3.068	0.562	29.77	1	**0**	21.5	7.141	64.73
COA (malicious)	0.44	0.471	0.87	1	0.351	1.552	0.616	3.911
COA (ABM)	-1.093	0.654	2.792	1	0.095	0.335	0.093	1.208
COA (shot)	0.36	0.471	0.583	1	0.445	1.433	0.569	3.607

NB: Significant *p* values are bold

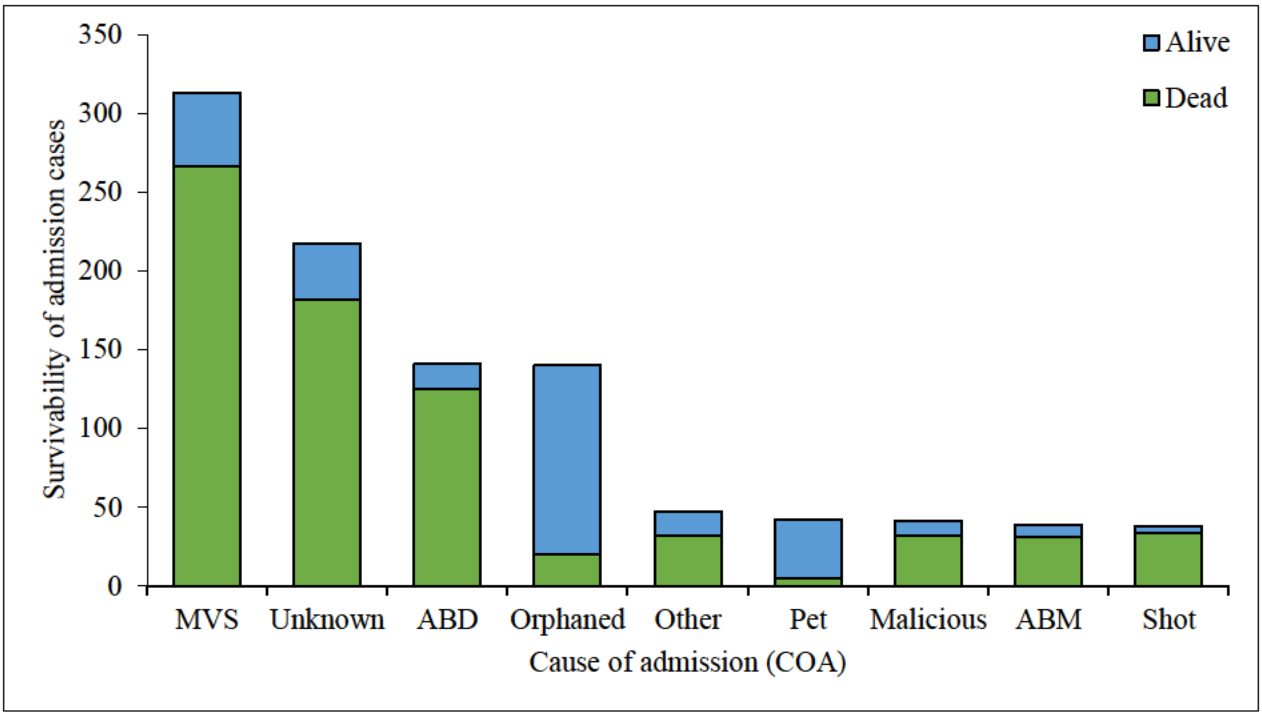


Fig. 3.8. Survivability of vervet monkey admissions admitted to an urban wildlife rehabilitation centre between 2011 and 2018 in the present study.

3.5 Discussion

3.5.1 Vervet monkey admissions

We present data on 1018 admission cases of vervets admitted to a wildlife rehabilitation centre, CROW, in Durban, eThekwini Municipality, KwaZulu-Natal, South Africa, between January 2011 and December 2018. Our study aimed to understand the trends in key factors contributing to conflict events between humans and vervets, and the collective interactions of aspects such as season, sex, age, geographical location, causes of admission, and survivability to determine how particular HWC influences their demise. The long-term data explain the plight and conditions that vervets face in urban-forest landscape mosaics such as eThekwini Municipality. Therefore,

providing evidence to support conflict mitigation and recommendations for 'problem' species in a shared landscape is critical to avoid the comprised welfare and local extinction of the species.

We found a considerable number of members of the public reporting injured vervets to the centre through telephonic calls to the centre's main contact number. Although public perceptions of vervets are divided on the likeability of this 'pest' species (Patterson et al., 2017), people made an effort to report injured vervets to the centre. More notably, 25% of people went to the extent of dropping off an injured vervet at the centre for treatment. These findings support the suggestion that some people perceive this primate positively and would help an animal in distress (Alexander, 2000; Mormile and Hill, 2017). Other wildlife rehabilitation centres like the Society for the Prevention of Cruelty to Animals (SPCA) and other primate or wildlife rehabilitation centres from KwaZulu-Natal also used CROW as a drop-off point for vervets. Since these centres were often at full capacity or unable to accommodate the vervets at the time (pers. comm.), CROW was the nearest and biggest centre in terms of space to assist. The central district of eThekwini Municipality was the location reported with the highest vervet admission cases. The proximity of the centre to most urban dwellers living in the central district and increased public awareness could explain the high admission cases as depicted in the vicinity closest to CROW. The number of vervets admitted alive to the centre was significant at 83.7%. This further asserts the sentiments of concern from the greater public of KwaZulu-Natal, that they would rather prefer to assist an injured or dying animal than to see it suffer.

Over the study period, significantly more males than female vervets, across all age classes, were reported to the centre, possibly because of their home range size and activities. This is of concern as studies on vervet troops in the wild have shown higher female to male sex ratios (Pasternak et al., 2013). Vervet monkeys are sexually dimorphic, with males occupying larger

home ranges than females in terms of feeding and mating habits, which could have contributed to higher admissions (Isbell et al., 1990; Patterson et al., 2019). Furthermore, females are philopatric and stay bonded within the troop because of their social structure, often moving close with the younger individuals, while dominant males often move ahead of the troop (Teichroeb et al., 2015). Juveniles were the highest reported age class of vervets, as similarly documented by Wimberger and Downs (2010). Teichroeb et al. (2015) reported the spatial positioning of juveniles is often left behind at the back of the troop because they were still scrounging for leftovers and busy eating. This can be hazardous in urban areas as there are numerous anthropogenic risks. We also note that a substantial number of juveniles could not be sexed because of extreme bodily injuries, further exacerbating the danger vervets face in the urban-forest landscape mosaic. Juvenile males were the highest admitted cases, which can be attributed to their risk-taking behaviour (Fairbanks, 1993; Blaszczyk, 2017). During peak times of wildlife admissions, some vervet's sex or age class were not recorded (pers. comm.), assuming the centre's rush of intakes at the time.

Most vervets that were severely injured on arrival, died in transition or had to be euthanised. Rehabilitators at the centre are tasked with the decision of euthanasia. This humane solution is regarded as the most viable option to minimise the pain or suffering specifically when the animal's life cannot be saved, an illness cannot be cured, or not enough resources available to accommodate each sick or injured animal (Hanger and Tribe, 2005). Furthermore, severely injured vervets could not be released back into the wild if they could not survive using their natural or physical capabilities. Mortality is inevitable, considering failed medical treatment or unresponsive treatment attributable to the severity of illness or injury. On the other hand, 27% could be rehabilitated and kept alive at the centre for recuperation until eventual release. In contrast, no more than 1% could be immediately released back into the wild if healthy and unharmed.

3.5.2 Trends in admissions

As predicted, we did observe significant trends across the years and months of vervets admitted to the centre. The annual increase in admissions demonstrates the scale of the problem in the urban-forest mosaic landscape of eThekwini Municipality, which justifies an effective management proposal for this primate species. Increasing admission cases can be linked to urbanisation and the reduction of pristine natural habitats for vervets (Alexander et al., 2021). There has been a constant increase in urban development infringing on green ecosystems because of population growth in eThekwini Municipality (Otunga et al., 2014). Furthermore, unemployment and poverty place low-income individuals living in high densities in informal settlements in environmentally sensitive areas, whereas old sugar cane farms are being converted to upmarket eco-estates for the affluent (eThekwini Municipality, 2021). Land-use change is the biggest driver of habitat loss of green areas and contributes to human-vervet conflict, which will continue to increase as trends show (Taylor-Brown et al., 2019; Burroughes et al., 2021; Dessalvi et al., 2021).

Overall, reported admission cases were highest in November and December, accounting mainly for human activities and behaviour of vervets. The longer hours of sunlight during these months increase vervet activity (McFarland et al., 2014; Thatcher et al., 2019a). Vervets' activity budgets are generally higher in the wet and warmer months because of increased foraging, socialising, and active birthing events (Baldellou and Adan, 1998; Canteloup et al., 2019). Additionally, December is a peak period for holidaymakers, and the coastal province of KwaZulu-Natal brings in high volumes of tourists (Wyllie and Tifflin, 2020). The influx of people and outdoor recreational activities to the area increases direct interactions with vervets. Additionally, there is an abundance of anthropogenic food scraps during this period, resulting in vervets foraging

openly in garbage tip sites aggravating HWC (Newsome and Van Eeden, 2017). Since outdoor recreational activities are elevated during the festive period, more cases could have been reported to the centre. The lowest admission cases were reported in February, and this could be caused by the warmest month in eThekwini Municipality, with an average high temperature of 26.5°C and the month with the most sunshine, an average of 8.5 h (SAWS, 2021). The extreme heat deters movement of vervets, and resting is greater, possibly reducing the overall admissions since their movement generally decreases during the hotter months of January and February (McFarland et al., 2014; Thatcher et al., 2019a).

We observed a distinct temporal pattern of admissions seasonally, with a peak in admission cases in spring and the lowest in winter, similarly observed in the study by Healy and Nijman (2014). Taking into account the sex and age classes of vervets, only spring had more females than males admitted, possibly because of the birthing season and the added complications experienced by females, particularly during parturition (Fairbanks and McGuire, 1984, pers. comm.) Male vervets have more flexibility over their ranging behaviour and are known to disperse from their natal troops before reaching sexual maturity, especially during the breeding season (De Moor and Steffens, 1972; Cheney and Seyfarth, 1983; Schoof et al., 2009) accounting for high admission cases in autumn as revealed in this study. Adult vervets' admittance was highest in spring and lowest in summer, while infants' admittance was highest in summer and lowest in winter, indicative of the gestation and birthing periods occurring in the warmer, wetter season, with the fewest births occurring in winter. Juveniles admitted in autumn and winter were the highest across all age classes and seasons, probably because of food scarcity or emigration of lower-ranking individuals (Cheney and Seyfarth, 1983; Van Vuren and Isbell, 1996). The general admission of adults across the seasons could have affected the population of adults in the wild. This might have

led to juveniles and subadults fending for themselves and displaying risky behaviour (Fairbanks et al., 2004). The central and inner west districts of eThekwini Municipality accounted for similar patterns of admissions throughout the seasons, peaking in autumn. These districts consist of urban and suburban gardens with forest patches that vervet troops frequent (Patterson et al., 2018; Zungu et al., 2020). In autumn, there was a decrease in admissions from outside eThekwini Municipality and other municipalities, further emphasising those urban districts accounted for more admissions in vervets' breeding and dispersal season. Low admissions could also be accounted for considering the locality of the centre, suggesting that further away the distance of the centre led to lower reported incidences. The geographic landscape and human population density are less concentrated away from the central district of eThekwini Municipality, thus suggesting less HWC. The final outcome of vervets euthanised or that died after admission was highest in autumn and winter; respectively, they could not survive because of the severity of their injuries. Captive vervets were highest in spring, suggesting that it was possible to save individuals as their injuries were not fatal. Determining seasonal effects on the final outcome can assist rehabilitators with pre-emptive decisions on wildlife rehabilitation, especially in urban areas (Sherman et al., 2020).

3.5.3 Causes of admission

The most common cause of vervets' admission was motor vehicle strikes. Prior studies have documented vehicle collisions as the leading cause of primate deaths (McLennan and Asiimwe, 2016; Hetman et al., 2019). This has also been documented at a specialist vervet rehabilitation centre in Limpopo Province, South Africa (56%, $N = 50$) (Healy and Nijman, 2014). High motor vehicle strikes can be attributed to urban areas typically associated with higher road densities. In addition, the vervets use roads as pathways for troop movements in the urban-forest mosaic

landscape (Patterson et al., 2018). Our study reported a considerably high number of admissions in autumn. During this time, vervets are particularly vulnerable to the risk of collisions by vehicles as they expand their home ranges in search and fight for females (Cheney and Seyfarth, 1990). In autumn, the biggest driver of home ranging behaviour is breeding for males and females (Henzi and Lucas, 1980), resulting in strikes in high traffic areas. The second most reported admissions were termed 'unknown'. Unknown causes of vervet admissions admitted included already sickly, emaciated monkeys, and weak when admitted with no historical context of the admission documented. Unknown causes of admissions were previously documented in wildlife rehabilitation centres (Cheney and Seyfarth, 1990; Molina-Lopez et al., 2017; Garcês et al., 2019). The third highest cause of admissions was domestic dogs attacking vervets. Pet attacks by dogs were also previously documented in vervet admissions and are certainly another source of anthropogenic pressure on vervets in the urban mosaic landscape (Healy and Nijman, 2014; Long et al., 2020). Most dog attacks are fatal (Fernandes et al., 2020), with kidney lesions common when dogs attack primates. The highest attacks by dog cases were in winter, probably because of relatively low natural food to forage, which led to vervets entering gardens and homes with pets searching for food scraps (Thatcher et al., 2019b). Considerably, most injurious and fatal dog attacks on primates occurred near human settlements, similar to our study (Anderson, 1986). Surprisingly, Patterson et al. (2018) revealed increased levels of vervets playing in gardens with dogs in the urban-forest landscape mosaic, possibly attributing to the high admission cases documented in this study. Presently the primary predator of vervets is domestic dogs, specifically in human-modified areas (Teichroeb et al., 2015). The fourth highest cause of admissions was orphaned vervets, recorded highest during the warmer seasons of spring and summer and when mostly infants, typical of their natural birthing cycle, were admitted (Fairbanks and McGuire,

1984; Healy and Nijman, 2014). Orphaned vervets came into the centre when their mothers were directly impacted by the various cause of admissions and were immediately taken to the nursery for hand-rearing. Orphans were housed in captivity with other rehabilitating monkeys for release when they were older.

For each of the causes of admissions: other, pet, malicious, attacked by another monkey, and shot, accounted for less than 5% in this study. However, this still showed the challenges that vervets face in urban areas. The cause of admissions regarded under 'other' comprised of vervets admitted for being caught or stuck in a fence, stung by bees, fell from an object like a tree, wall, or building, electrocuted by a transformer or electrical wiring, and/or pregnancy complications experienced by females who had difficulties during birth. These result from the human-modified landscape. Our study also found that some people kept vervets as pets; often found lost, abandoned, or sold for money. In South Africa, removing and keeping wild animals as pets is illegal and detrimental to the welfare of wildlife, especially when an animal becomes habituated to the presence of people (Grobler et al., 2006; Guy and Curnoe, 2013; Healy, 2017). Once habituated, any wild animal can experience difficulties being released back into the wild because it has lost its fear for humans, its instincts to survive in the wild, and could have developed diseases that can infect wild populations (Burton and Doblar, 2004). Although infant vervets are cute and appealing to keep, people should avoid hand-rearing at all costs and rather report this to the national conservation authority or rehabilitation centre. The public does not have adequate support and equipment to hand-rear infant wildlife. The centre reported some vervets brought to the centre wearing human diapers and playing with infant toys. This happens typically when pet vervets become unmanageable and show aggression (pers. comm.). Admission cases also recorded malicious harm or injury inflicted directly by a person through a physical attack, poisoned and

painted. Although these were a few cases, they highlighted animal cruelty and the extent to which people will go to deal with the 'problem' of vervets.

Few cases of admissions of vervets attacked by another monkey were also brought to the centre, and this generally took place during the mating seasons of autumn when males dispersed or attempted mating with females within the troop. Aggression between males and female were observed in wild populations, and this could explain the attacks on each other (Cheney, 1981). Vervets were admitted for being shot at with pellet guns. On several occasions when vervets were admitted for any of the above reasons, x-rays showed metal pellets lodged in the body. In some cases, vervets can survive with the pellets lodged in their flesh without deterring their natural abilities; however, lethal shots to the head or spine result in death (pers. comm.).

3.5.4 Survivability

The binary logistic regression results established a relationship between anthropogenic pressures and the survivability of vervets admitted to the centre. Although several significant factors (season, location in the municipality, age, cause of admission) for whether a vervet was dead or alive at the end of the admission process, the predictor responsible for most admission cases surviving admission was the cause of admission being a pet. Additionally, the chances of surviving were high for attacked by a dog, other, malicious, and shot. Using models to predict admissions can assist rehabilitation centres like CROW in determining, before the process of admission, whether an animal will survive (Molony et al., 2007; Maphalala et al., 2021). Notably, of the 83.7% admitted alive at the beginning of intake, only 34.2% survived.

Admission record data from an urban wildlife rehabilitation centre in eThekwini Municipality of South Africa highlighted the trends, seasons, causes and survivability of an Old World primate species that encountered multiple anthropogenic challenges in the urban-forest

landscape mosaic. There exists a preconceived notion from the public in eThekwini Municipality that the population of vervets is expanding. Though we did not quantify the total population of vervets in eThekwini Municipality to determine the effects of mortality on the overall population, further studies are required. An overabundance of vervets cannot explain the high levels of human-vervet conflict, but rather there is an increased presence of vervets in human landscapes because of opportunities created by artificial food sources vervets have adapted to live close to humans and human-modified landscapes (Fuentes, 2006). Instead of opposing wildlife interactions in urban areas, the most promising future approach will incorporate resilience to conflict via human governance and education. Educating people on how to live with vervet monkeys could reduce conflict, specifically in urban, industrial, and greater suburbia, and this was noted by people reporting cases actively throughout the years. CROW has played an active role in community involvement and active education initiatives (pers. comm.).

3.5.5 Conclusions

This retrospective study found an increase in trends of admission records over an eight-year period of vervets in the urban-forest mosaic landscape of eThekwini Municipality in South Africa. Previous studies have highlighted vervets at rehabilitation centres but never from one established in the central region of an urban area with long-term data highlighting HWC was lacking in the scientific domain. Information gathered from admission records provides the support needed to determine how vervets are impacted in urban areas, particularly HWC. Additionally, admission records in this study report on hot-spot areas of eThekwini Municipality and assess the importance of wildlife rehabilitation centres in urban areas. Given the above, comprehensive data collated and collected from wildlife rehabilitation centres provide large extensive databases with opportunities

for further analysis through research. Scientists and animal welfare organisations, who work independently, can provide valuable evidence for wildlife management through shared conservation efforts.

3.6 Acknowledgements

We would like to thank the Centre for Rehabilitation of Wildlife staff and volunteers for their continued partnership in this study and determined efforts in protecting and rehabilitating wildlife. Also, special thanks are given to Taylor Hill, Paul Hoyte, Clint Halkett-Siddall, and the clinic staff of CROW for the interpretation of data and rehabilitation experiences. We thank Erin Adams for assistance with map work and Machawe Maphalala for statistical support. We would also like to acknowledge The National Research Foundation (NRF) (ZA, Grant 98404) and Durban Research Action Partnership (DRAP, ZA) for financial support of this study.

3.7 References

Alexander, J., Smith, D.A.E., Smith, Y.C.E., Downs, C.T., 2021. Urban land development for biodiversity: suggested development and management guidelines for eco-estates using case studies from coastal KwaZulu-Natal, South Africa. Urban For. Urban Green. 65, 127347. https://doi.org/10.1016/j.ufug.2021.127347.

Alexander, S.E., 2000. Resident attitudes towards conservation and black howler monkeys in Belize: the Community Baboon Sanctuary. Environ. Conserv. 27, 341-350. http://doi:10.1017/S0376892900000394.

Anand, S., Radhakrishna, S., 2017. Investigating trends in human-wildlife conflict: is conflict escalation real or imagined? J. Asia Pac. Biodivers. 10, 154-161. https://doi.org/10.1016/j.japb.2017.02.003.

Anderson, J.R., 1986. Encounters between domestic dogs and free-ranging non-human primates. Appl. Anim. Behav. Sci. 15, 71-86. https://doi.org/10.1016/0168-1591(86)90024-9.

Baldellou, M., Adan, A., 1998. Diurnal and seasonal variations in vervet monkeys' activity. Psychol. Rep 83, 675-685. https://doi.org/10.2466/pr0.1998.83.2.675.

Blaszczyk, M.B., 2017. Boldness towards novel objects predicts predator inspection in wild vervet monkeys. Anim. Behav. 123, 91-100. https://doi.org/10.1016/j.anbehav.2016.10.017.

Burroughes, N.D., Dowler, J., Burroughes, G., 2021. Admission and Survival Trends in Hedgehogs Admitted to RSPCA Wildlife Rehabilitation Centres Proc. Zool. Soc. 74, 198-204. https://doi.org/10.1007/s12595-021-00363-9.

Burton, D.L., Doblar, K.A., 2004. Morbidity and mortality of urban wildlife in the midwestern United States. Proceedings 4th International Urban Wildlife Symposium. Shaw et al., (Eds.), 171-181. https://citeseerx.ist.psu.edu/viewdoc/download.

Butynski, T.M., De Jong, Y.A., 2019. *Chlorocebus pygerythrus*. IUCN Red List Threat. Species, e-T136271A17957823. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T136271A17957823.en

Cancelliere, E.C., Chapman, C.A., Twinomugisha, D., Rothman, J.M., 2018. The nutritional value of feeding on crops: Diets of vervet monkeys in a humanized landscape. Afr. J. Ecol. 56, 160-167. https://doi.org/10.1111/aje.12496.

Canteloup, C., Borgeaud, C., Wubs, M., van de Waal, E., 2019. The effect of social and ecological factors on the time budget of wild vervet monkeys. Ethol. 125, 902-913. https://doi.org/10.1111/eth.12946.

Cheney, D.L., 1981. Intergroup encounters among free-ranging vervet monkeys. Folia Primatol. 35, 124-146. https://doi.org/10.1159/000155970 .

Cheney, D.L., Seyfarth, R.M., 1983. Nonrandom dispersal in free-ranging vervet monkeys: social and genetic consequences. Am. Nat. 122, 392-412. https://doi.org/10.1086/284142.

Cheney, D.L., Seyfarth, R.M., 1990. How monkeys see the world: Inside the mind of another species. University of Chicago Press. Chicago.

COGTA, 2020. eThekwini Metropolitan KZN, In Metro Profile Ethekwini. https://www.cogta.gov.za/ddm/wp-content/uploads/2020/07/Metro-Profile_Ethekwini.pdf.

De Moor, P.P., Steffens, F.E., 1972. The movements of vervet monkeys (*Cercopithecus aethiops*) within their ranges as revealed by radio-tracking. J. Anim. Ecol. 677-687. : https://www.jstor.org/stable/3202.

Dessalvi, G., Borgo, E., Galli, L., 2021. The contribution to wildlife conservation of an Italian Recovery Centre. Nat. Conserv. 44, 1. http://doi:10.3897/natureconservation.44.65528.

Dickman, A.J., 2012. From cheetahs to chimpanzees: a comparative review of the drivers of human-carnivore conflict and human-primate conflict. Folia Primatol. 83, 377-387. https://doi.org/10.1159/000339812.

Distefano, E., 2005. Human-Wildlife Conflict worldwide: collection of case studies, analysis of management strategies and good practices. Food and Agricultural Organization of the United Nations (FAO), Sustainable Agriculture and Rural Development Initiative (SARDI), Rome, Italy. Available from: FAO Corporate Document repository http://www.fao.org/documents.

Downs, C.T., Alexander, J., Brown, M., Chibesa, M., Smith, Y.C.E., Gumede, S.T., Hart, L., Josiah, K.K., Kalle, R., Maphalala, M., et al., 2021. Modification of the third phase in the framework for vertebrate species persistence in urban mosaic environments. Ambio, 1-13. https://doi.org/10.1007/s13280-021-01501-5.

EPCPD, 2020. Durban: State of Biodiversity Report 2019/2020. © eThekwini Municipality, 2020. http://www.durban.gov.za/City_Services/.

eThekwini Municipality, 2021. Municipal Spatial Development Framework 2021-2022. Final Report May 2021. http://www.durban.gov.za/City_Services/

Fairbanks, L.A., 1993. Risk-taking by juvenile vervet monkeys. Behaviour 124, 57-72. https://doi.org/10.1163/156853993X00506.
Fairbanks, L.A., Jorgensen, M.J., Huff, A., Blau, K., Hung, Y.Y., Mann, J.J., 2004. Adolescent impulsivity predicts adult dominance attainment in male vervet monkeys. Am. J. Primatol. 64, 1-17. https://doi.org/10.1002/ajp.20057.
Fairbanks, L.A., McGuire, M.T., 1984. Determinants of fecundity and reproductive success in captive vervet monkeys. Am. J. Primatol. 7, 27-38. https://doi.org/10.1002/ajp.1350070106.
Fernandes, N.C.C.d.A., do Nascimento, P.M., Sánchez-Sarmiento, A.M., Ressio, R.A., dos Santos Cirqueira, C., Kanamura, C.T., de Carvalho, J., da Silva, S.M.P., Peruchi, A.R., de Souza Junior, J.C., 2020. Histopathological kidney changes and myoglobinuria in neotropical non-human primates attacked by dogs, Brazil. J. Med. Primatol. 49, 65-70. https://doi.org/10.1111/jmp.12456.
Festus, I.A., Omoboye, I.F., Andrew, O.B., 2020. Urban sprawl: Environmental consequence of rapid urban expansion. Malaysian J Social Sci Human 5, 110-118. https://doi.org/10.47405/mjssh.v5i6.411.
Findlay, L., 2016. Human-primate conflict: An interdisciplinary evaluation of wildlife crop raiding on commercial crop farms in Limpopo Province, South Africa. PhD Thesis, Durham University. http://etheses.dur.ac.uk/11872/.
Findlay, L., Hill, R., 2020. Baboon and vervet monkey crop-foraging behaviors on a commercial South African Farm: Preliminary implications for damage mitigation. Human-Wildlife Interactions 14, 19. https://doi.org/10.26077/5dbc-b920.
Fischer, J.D., Schneider, S.C., Ahlers, A.A., Miller, J.R., 2015. Categorizing wildlife responses to urbanization and conservation implications of terminology. Conserv. Biol. 29, 1246-1248. https://www.jstor.org/stable/24483200.
Fuentes, A., 2006. Human-nonhuman primate interconnections and their relevance to anthropology. Ecol. Environ. Anthropol. 2, 1-11. https://digitalcommons.unl.edu/icwdmeea.
Garcês, A., Pires, I., Pacheco, F., Fernandes, L.S., Soeiro, V., Lóio, S., Prada, J., Cortes, R., Queiroga, F., 2019. Natural and anthropogenic causes of mortality in wild birds in a wildlife rehabilitation centre in northern Portugal: a ten-year study. Bird Study 66, 484-493. https://doi.org/10.1080/00063657.2020.1726874.
Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., Briggs, J.M., 2008. Global Change and the Ecology of Cities. Science 319, 756-760. https://doi.org/10.1126/science.1150195.
Grobler, P., Jacquier, M., deNys, H., Blair, M., Whitten, P.L., Turner, T.R., 2006. Primate sanctuaries, taxonomy and survival: a case study from South Africa. Ecol. Envir. Anth. 2, 1-16. https://digitalcommons.unl.edu/icwdmeea/2.
Guy, A.J., 2013. Release of rehabilitated *Chlorocebus aethiops* to Isishlengeni game farm in Kwazulu-Natal, South Africa. J. Nat. Conserv. 21, 214-216.
Guy, A.J., Curnoe, D., 2013. Guidelines for the rehabilitation and release of vervet monkeys. Primate Conserv. 2013, 55-63. https://doi.org/10.1896/052.027.0103.
Guy, A.J., Curnoe, D., Banks, P.B., 2013. A survey of current mammal rehabilitation and release practices. Biodivers. Conserv. 22, 825-837. https://doi.org/10.1007/s10531-013-0452-1.

Guy, A.J., Stone, O.M., Curnoe, D., 2011. The release of a troop of rehabilitated vervet monkeys (*Chlorocebus aethiops*) in KwaZulu-Natal, South Africa: outcomes and assessment. Folia Primatol (Basel) 82, 308-320. https://doi.org/10.1159/000337269.

Hanger, J., Tribe, A., 2005. Management of critically ill wildlife: The reality and practice of wildlife euthanasia. National Wildlife Rehabilitation Conference, 1-12. https://www.researchgate.net/profile/Jon-Hanger/.

Healy, A., 2017. Conservation of vervets, Africa's most ubiquitous primates. https://radar.brookes.ac.uk/radar/file.

Healy, A., Nijman, V., 2014. Pets and pests: vervet monkey intake at a specialist South African rehabilitation centre. Anim.Welf. 23, 353-360. http://doi:10.7120/09627286.23.3.353.

Henzi, S.P., Lucas, J.W., 1980. Observations on the inter-troop movement of adult vervet monkeys (*Cercopithecus aethiops*). Folia Primatol. 33, 220-235. https://doi.org/10.1159/000155936.

Hetman, M., Kubicka, A.M., Sparks, T.H., Tryjanowski, P., 2019. Road kills of non-human primates: a global view using a different type of data. Mammal Rev. 49, 276-283. https://doi.org/10.1111/mam.12158.

Hill, C.M., 2005. People, crops and primates: A conflict of interests. Commensalism and conflict: The human-primate interface, 40-59. https://www.researchgate.net/profile/Catherine-Hill.

Hill, C.M., Webber, A.D., 2010. Perceptions of nonhuman primates in human–wildlife conflict scenarios. Am. J. Primatol. 72, 919-924. https://doi.org/10.1002/ajp.20845.

Hunter, P., 2007. The human impact on biological diversity. EMBO reports 8, 316-318. https://doi.org/10.1038/sj.embor.7400951.

Isbell, L.A., Cheney, D.L., Seyfarth, R.M., 1990. Costs and benefits of home range shifts among vervet monkeys (*Cercopithecus aethiops*) in Amboseli National Park, Kenya. Behav. Ecol. Sociobiol. 27, 351-358. https://doi.org/10.1007/BF00164006.

Isbell, L.A., Etting, S.F., 2017. Scales drive detection, attention, and memory of snakes in wild vervet monkeys (*Chlorocebus pygerythrus*). Primates 58, 121-129. https://doi.org/10.1007/s10329-016-0562-y.

LaBarge, L.R., Hill, R.A., Berman, C.M., Margulis, S.W., Allan, A.T.L., 2020. Anthropogenic influences on primate antipredator behavior and implications for research and conservation. Am. J. Primatol. 82, e23087. https://doi.org/10.1002/ajp.23087.

Long, R.B., Krumlauf, K., Young, A.M., 2020. Characterizing trends in human-wildlife conflicts in the American Midwest using wildlife rehabilitation records. PLoS One 15, e0238805. https://doi.org/10.1371/journal.pone.0238805.

Loudon, J.E., Grobler, J.P., Sponheimer, M., Moyer, K., Lorenz, J.G., 2014. Using the Stable Carbon and Nitrogen Isotope Compositions of Vervet Monkeys. PLoS One 9, e100758. https://doi.org/10.1371/journal.pone.0100758.

Manfredo, M.J., 2015. Essays on human-wildlife conflict 10 years after the Durban World Parks Congress: An introduction. Hum. Dimens. Wildl. 20, 285-288. https://doi.org/10.1080/10871209.2015.1007181.

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. Afr. J. Ecol. 59, 510-517. https://doi.org/10.1111/aje.12851.

McFarland, R., Barrett, L., Boner, R., Freeman, N.J., Henzi, S.P., 2014. Behavioral flexibility of vervet monkeys in response to climatic and social variability. Am. J. Biol. Anthropol. 154, 357-364. https://doi.org/10.1002/ajpa.22518.
McKinney, M.L., 2002. Urbanization, biodiversity and conservation. Biosci. 52, 883-890.
McKinney, M.L., 2006. Urbanization as a major cause of biotic homogenization. Biol. Conserv. 127, 247-260. https://doi.org/10.1016/j.biocon.2005.09.005.
McLennan, M.R., Asiimwe, C., 2016. Cars kill chimpanzees: case report of a wild chimpanzee killed on a road at Bulindi, Uganda. Primates 57, 377-388. https://doi.org/10.1007/s10329-016-0528-0.
McPherson, S.C., Brown, M., Downs, C.T., 2016. Diet of the crowned eagle (*Stephanoaetus coronatus*) in an urban landscape: potential for human-wildlife conflict? Urban Ecosyst. 19, 383-396. https://doi.org/10.1007/s11252-015-0500-6.
McPherson, S., Sumasgutner, P., Hoffman, B., Padbury, B., Brown, M., Caine, T., Downs, C.T. 2021. Surviving the urban jungle: Anthropogenic threats, wildlife-conflicts, and management recommendations for African Crowned Eagles. Frontiers Ecol Evol 9, 662623. https://doi.org/10.3389/fevo.2021.662623
Mikula, P., Saffa, G., Nelson, E., Tryjanowski, P., 2018. Risk perception of vervet monkeys *Chlorocebus pygerythrus* to humans in urban and rural environments. Behav. Processes. 147, 21-27. https://doi.org/10.1016/j.beproc.2017.12.011.
Molina-Lopez, R.A., Manosa, S., Torres-Riera, A., Pomarol, M., Darwich, L., 2017. Morbidity, outcomes and cost-benefit analysis of wildlife rehabilitation in Catalonia (Spain). PLoS. One 12, e0181331. https://doi.org/10.1371/journal.pone.0181331.
Molony SE, B.P., Garland L, Cuthill IC, Harris S, 2007. Factors that can be used to predict release rates for wildlife casualties. Anim.Welf. 16, 361-367. https://www.researchgate.net/publication/263030807.
Mormile, J.E., Hill, C.M., 2017. Living with urban baboons: Exploring attitudes and their implications for local baboon conservation and management in Knysna, South Africa. Hum. Dimens. Wildl. 22, 99-109. https://doi.org/10.1080/10871209.2016.1255919.
Municipality, e., 2021. Municipal Spatial Development Framework 2021-2022, In: Final Report May 2021. p. 848.
Naughton-Treves, L., Treves, A., Chapman, C., Wrangham, R., 1998. Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacent forest. J. Appl. Ecol. 35, 596-606. https://doi.org/10.1046/j.1365-2664.1998.3540596.x.
Newsome, T.M., Van Eeden, L.M., 2017. The effects of food waste on wildlife and humans. Sustainability 9, 1269. https://doi.org/10.3390/su9071269.
Nuissl H., Siedentop S., 2021. Urbanisation and Land Use Change. In: Weith T., Barkmann T., Gaasch N., Rogga S., Strauß C., Zscheischler J. (Eds.), Sustainable Land Management in a European Context. Human-Environment Interactions, Springer, Cham. https://doi.org/10.1007/978-3-030-50841-8_5.
Otunga, C., Odindi, J., Mutanga, O., 2014. Land Use Land Cover Change in the fringe of eThekwini Municipality: Implications for urban green spaces using remote sensing. S. Afr. J. Geom. 3, 145-162. http://doi.org/10.4314/sajg.v3i2.3.
Parathian, H.E., McLennan, M.R., Hill, C.M., Frazão-Moreira, A., Hockings, K.J., 2018. Breaking through disciplinary barriers: human–wildlife interactions and multispecies ethnography. Int. J. Primatol. 39, 749-775. https://doi.org/10.1007/s10764-018-0027-9.

Pasternak, G., Brown, L.R., Kienzle, S., Fuller, A., Barrett, L., Henzi, S.P., 2013. Population ecology of vervet monkeys in a high latitude, semi-arid riparian woodland. Koedoe 55, 01-09. https://hdl.handle.net/10520/EJC132980PDF.

Patterson, L., Kalle, R., Downs, C., 2017. A citizen science survey: perceptions and attitudes of urban residents towards vervet monkeys. Urban Ecosys. 20, 617. https://doi.org/10.1007/s11252-016-0619-0.

Patterson, L., Kalle, R., Downs, C., 2018. Factors affecting presence of vervet monkey troops in a suburban matrix in KwaZulu-Natal, South Africa. Landsc. Urban Plan. 169, 220-228. https://doi.org/10.1016/j.landurbplan.2017.09.016.

Patterson, L., Kalle, R., Downs, C.T., 2019. Living in the suburbs: Space use by vervet monkeys (*Chlorocebus pygerythrus*) in an eco-estate, South Africa. Afr. J. Ecol. 57, 539-551. https://doi.org/10.1111/aje.12629.

Peterson, M.N., Birckhead, J.L., Leong, K., Peterson, M.J., Peterson, T.R., 2010. Rearticulating the myth of human-wildlife conflict. Conserv. Lett. 3, 74-82. https://doi.org/10.1111/j.1755-263X.2010.00099.x.

Saj, T.L., 1998. The ecology and behavior of vervet monkeys in a human-modified environment. Master Thesis, University of Calgary, Calgary, AB. http://doi:10.11575/PRISM/24292.

SAWS, 2021. South African Weather Services, eThekwini Municipality – Durban Forecast. https://www.weathersa.co.za/.

Schoof, V.A.M., Jack, K.M., Isbell, L.A., 2009. What traits promote male parallel dispersal in primates? Behaviour, 701-726. http://www.jstor.org/stable/40296002.

Schwarz, N., Moretti, M., Bugalho, M.N., Davies, Z.G., Haase, D., Hack, J., Hof, A., Melero, Y., Pett, T.J., Knapp, S., 2017. Understanding biodiversity-ecosystem service relationships in urban areas: A comprehensive literature review. Ecosyst. Serv. 27, 161-171. https://doi.org/https://doi.org/10.1016/j.ecoser.2017.08.014.

Seoraj-Pillai, N., Pillay, N., 2017. A meta-analysis of human–wildlife conflict: South African and global perspectives. Sustainability 9, 34. https://doi.org/10.3390/su9010034.

Sherman, J., Ancrenaz, M., Meijaard, E., 2020. Shifting apes: Conservation and welfare outcomes of Bornean orangutan rescue and release in Kalimantan, Indonesia. J. Nat. Conserv. 55, 125807. https://doi.org/10.1016/j.jnc.2020.125807.

Siljander, M., Kuronen, T., Johansson, T., Munyao, M.N., Pellikka, P.K., 2020. Primates on the farm – spatial patterns of human–wildlife conflict in forest-agricultural landscape mosaic in Taita Hills, Kenya. Appl. Geogr. 117, 102185. https://doi.org/10.1016/j.apgeog.2020.102185.

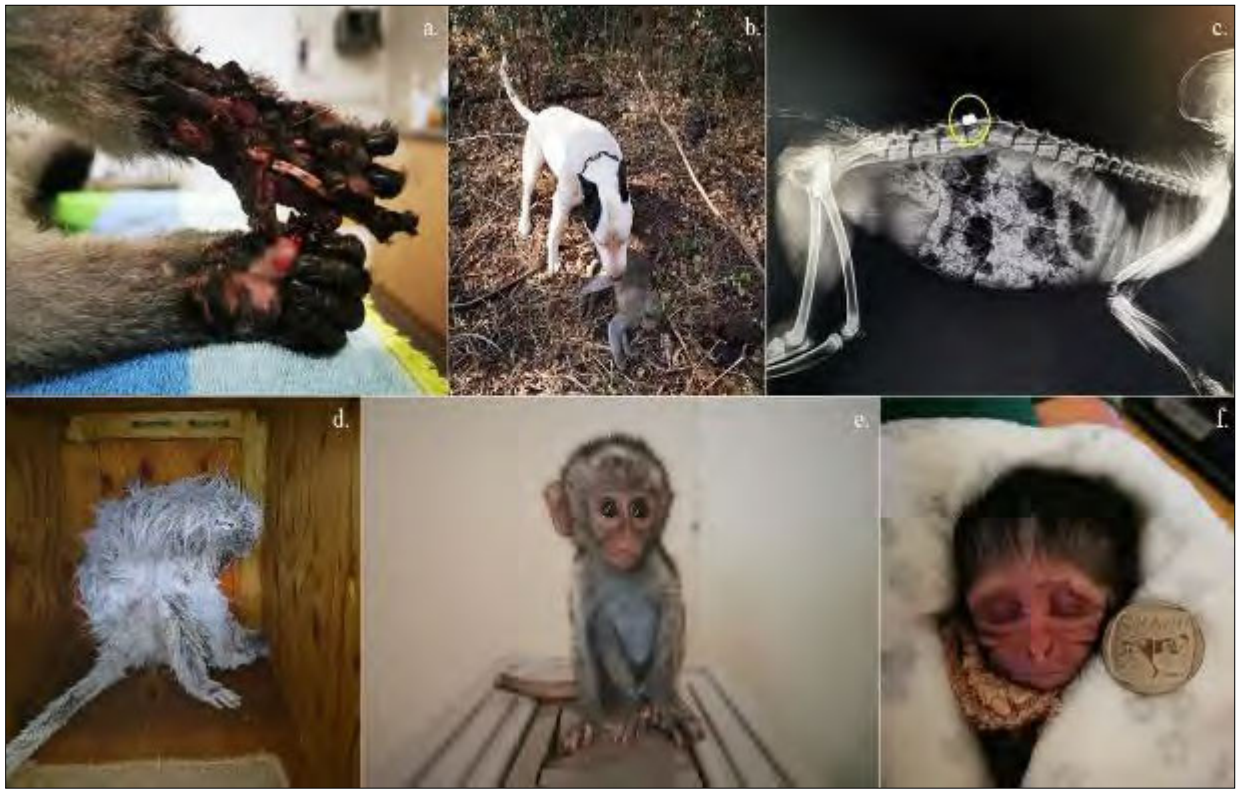
Sillero-Zubiri, C., Switzer, D., 2001. Crop raiding primates: searching for alternative, humane ways to resolve conflict with farmers in Africa. Wildlife Conservation Research Unit, Oxford University, Oxford. http://www.peopleandwildlife.org.uk/crmanuals/CropRaidingPrimatesP&WManual.

Skinner, J.D., Chimimba, C.T., 2005. The Mammals of the Southern African Sub-Region. Cambridge University Press. Cape Town, South Africa.

Smart, S.M., Thompson, K., Marrs, R.H., Le Duc, M.G., Maskell, L.C., Firbank, L.G., 2006. Biotic homogenization and changes in species diversity across human-modified ecosystems. Proc. R. Soc. B: Biol. Sci. 273, 2659-2665. https://doi.org/10.1098/rspb.2006.3630.

Soulsbury, C.D., White, P.C.L., 2015. Human-wildlife interactions in urban areas: a review of conflicts, benefits and opportunities. Wildl. Res. 42, 541. https://doi.org/10.1071/wr14229.
Soulsbury, C.D., White, P.C.L., 2019. A Framework for assessing and quantifying human-wildlife interactions in urban areas. In: Frank, B., Glikman, J.A., and Marchini, S. (Ed.) Human-wildlife interactions:Turning conflict into coexistence. 107-128.
Taylor-Brown, A., Booth, R., Gillett, A., Mealy, E., Ogbourne, S.M., Polkinghorne, A., Conroy, G.C., 2019. The impact of human activities on Australian wildlife. PLoS One 14, e0206958. https://doi.org/10.1371/journal.pone.0206958.
Teichroeb, J.A., White, M.M., Chapman, C.A., 2015. Vervet (*Chlorocebus pygerythrus*) intragroup spatial positioning: dominants trade-off predation risk for increased food acquisition. Int. J. Primatol. 36, 154-176. https://doi.org/10.1007/s10764-015-9818-4
Thatcher, H.R., Downs, C.T., Koyama, N.F., 2019a. Anthropogenic influences on the time budgets of urban vervet monkeys. Landsc. Urban Plan. 181, 38-44. https://doi.org/10.1016/j.landurbplan.2018.09.014.
Thatcher, H.R., Downs, C.T., Koyama, N.F., 2019b. Positive and negative interactions with humans concurrently affect vervet monkey (*Chlorocebus pygerythrus*) ranging behavior. Int. J. Primatol. 40, 496-510. https://doi.org/10.1007/s10764-019-00099-6.
Turner, T., Hill, R., Coetzer, W., Patterson, L., 2016. A Conservation Assessment of *Chlorocebus pygerythrus*. South Africa: South African National Biodiversity Institute and Endangered Wildlife Trust.
UN, 2018. United Nations, World Urbanization Prospects 2018. Population Division (2019), Department of Economic and Social Affairs.
Van Vuren, D., Isbell, L.A., 1996. Differential costs of locational and social dispersal and their consequences for female group-living primates. Behaviour 133, 1-36. https://doi.org/10.1163/156853996X00017.
Warren, Y., 2009. Crop-raiding baboons (*Papio anubis*) and defensive farmers: a West African perspective. West Afr. J. Appl. Ecol. 14. https://doi.org/10.4314/wajae.v14i1.44705 .
Werner, P., 2011. The ecology of urban areas and their functions for species diversity. Landsc. Ecol. Eng. 7, 231-240. https://doi.org/10.1007/s11355-011-0153-4.
Wyllie, R. Wayne, T., 2020. Tourism KwaZulu-Natal Statistics Report. Statistics for the Tourism Sector (2019). https://www.kznedtea.gov.za/documents/Tourism%20KZN%20Statistical%20Report%20-%20December%202020.pdf
Wimberger, K., Downs, C.T., 2010. Annual intake trends of a large urban animal rehabilitation centre in South Africa: a case study. Anim.Welf. 19, 501. https://www.academia.edu/21250803/.
Zungu, M.M., Maseko, M.S.T., Kalle, R., Ramesh, T., Downs, C.T., 2020. Factors affecting the occupancy of forest mammals in an urban-forest mosaic in EThekwini Municipality, Durban, South Africa. Urban For. Urban Green. 48, 126562. https://doi.org/10.1016/j.ufug.2019.126562.

3.8 Supplementary information



Supplementary information Fig. S3.1. Various causes of admissions of vervet monkeys admitted to an urban wildlife rehabilitation centre in KZN, SA, showing evidence of a. vervet hands electrocuted by transmitter, b. vervet attacked by dog, c. x-ray revealing pellet on vervet spinal cord, d. vervet that was painted, e. vervet kept as pet that had its fur shaved off and tail cut, and f. orphaned infant vervet.

Supplementary information Table S3.1. List of causes of admission (COA) and grouped causes studied between 2011 and 2018.

Cause of admission	Grouped causes
• Attacked by monkey (ABM)	
• Attacked by dog (ABD)	
• Malicious harm/injury	– Attacked by person – Attacked by something/unknown – Painted – Poisoned
• Motor vehicle strike (MVS)	– Car – Bus – Truck – Train
• Orphaned	– Mother ABD (attacked by dog) – Mother MVS (motor vehicle strike) – Mother shot – Found alone (orphaned)
• Other	– Caught in fence – Fell – Electrocuted – Pregnancy complications – Stuck – Stung
• Pet	– Kept as pet – Sold as pet
• Shot	
• Unknown	– Found on ground – No record of COA (cause of admission)

Supplementary information Table S3.2. Descriptions of all variables selected to be used in the binary logistic regression for vervets admitted to an urban wildlife rehabilitation centre.

Variable	Type	Description
Survivability	Categorical	Dependent variable: Dead = 0; Alive = 1
Season	Categorical	spring
		summer
		autumn
		winter
Within the eThekwini Municipality	Categorical	out of the EM
		In the EM
		unknown location
Sex	Categorical	male
		female
		undetermined
Age class	Categorical	infant
		juvenile
		subadult
		adult
Cause of admission	Categorical	MVS
		unknown
		ABD
		orphaned
		other
		pet
		malicious
		ABM
		shot

Supplementary information Table S3.3. Sexes and age classes-groups of vervet admission cases reported to an urban wildlife rehabilitation centre between 2011 and 2018.

Age class	Sex									
	Female		Male		Not recorded		Undetermined		Total	
	N	%	N	%	N	%	N	%	N	%
Adult	159	42.3	177	34.0	2	6.3	2	2.2	340	33.4
Infant	69	18.4	113	21.7	3	9.4	19	21.3	204	20.0
Juvenile	112	29.8	184	35.3	20	62.5	51	57.3	367	36.1
Subadult	36	9.6	47	9.0	4	12.5	11	12.4	98	9.6
Unknown	0	0.0	0	0.0	3	9.4	6	6.7	9	0.9
Total	**376**	**100.0**	**521**	**100.00**	**32**	**100.0**	**89**	**100.0**	**1018**	**100.0**

Supplementary information Table S3.4. Summary of vervet monkey admissions to CROW from 2011 to 2018.

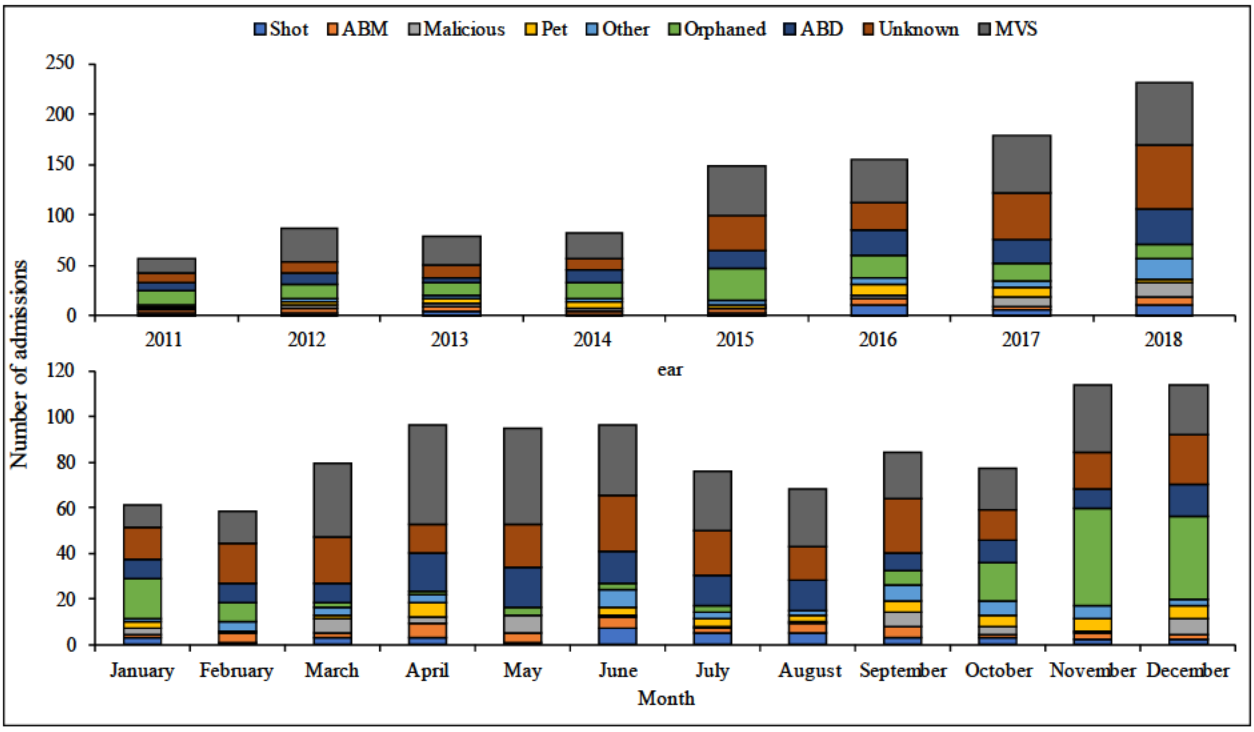
Variable	Category	N	%	Total	%
Year	2011	57	5.60	1018	100.00
	2012	87	8.55		
	2013	79	7.76		
	2014	82	8.06		
	2015	149	14.64		
	2016	155	15.23		
	2017	178	17.49		
	2018	231	22.69		
Month	January	61	5.99	1018	100.00
	February	58	5.70		
	March	79	7.76		
	April	96	9.43		
	May	95	9.33		
	June	96	9.43		
	July	76	7.47		
	August	68	6.68		
	September	84	8.25		
	October	77	7.56		
	November	114	11.20		
	December	114	11.20		
Season	Spring	275	27.01	1018	100.00
	Summer	233	22.89		
	Autumn	270	26.52		
	Winter	240	23.58		

Supplementary information Table S3.5. Summary of Chi-square test of independence for seasons.

	Season		
Chi-square results	χ^2	**df**	***p***
Sex	19.848	9	0.019
Age class	133.413	12	<0.05
Location of EM	28.420	15	0.019
Cause of admission	160.939	24	<0.05
Final outcome	80.718	9	<0.05

Supplementary information Table S3.6. Seasonal comparisons of vervet admission cases reported to an urban wildlife rehabilitation centre between 2011 and 2018.

		Season								Total	
		Spring		Summer		Autumn		Winter			
		N	%	N	%	N	%	N	%	N	%
Sex	female	126	45.82	84	36.05	88	32.59	78	32.50	376	36.94
	male	122	44.36	127	54.51	143	52.96	129	53.75	521	51.18
	not recorded	5	1.82	6	2.58	14	5.19	7	2.92	32	3.14
	undetermined	22	8.00	16	6.87	25	9.26	26	10.83	89	8.74
Age	adult	91	33.09	72	30.90	98	36.30	79	32.92	340	33.40
	infant	83	30.18	85	36.48	29	10.74	7	2.92	204	20.04
	juvenile	81	29.45	52	22.32	109	40.37	125	52.08	367	36.05
	subadult	19	6.91	23	9.87	30	11.11	26	10.83	98	9.63
	unknown	1	0.36	1	0.43	4	1.48	3	1.25	9	0.88
District of EM	Central	117	42.55	97	41.63	145	53.70	117	48.75	476	46.76
	Inner West	69	25.09	57	24.46	78	28.89	67	27.92	271	26.62
	North	10	3.64	10	4.29	8	2.96	9	3.75	37	3.63
	other	57	20.73	47	20.17	24	8.89	30	12.50	158	15.52
	Outer West	8	2.91	10	4.29	8	2.96	6	2.50	32	3.14
	South	14	5.09	12	5.15	7	2.59	11	4.58	44	4.32
Cause of admission	ABD	26	9.45	31	13.30	44	16.30	40	16.67	141	13.85
	ABM	9	3.27	7	3.00	12	4.44	11	4.58	39	3.83
	Malicious	11	4.00	10	4.29	17	6.30	3	1.25	41	4.03
	MVS	68	24.73	46	19.74	117	43.33	82	34.17	313	30.75
	Orphaned	66	24.00	62	26.61	6	2.22	6	2.50	140	13.75
	Other	19	6.91	8	3.43	7	2.59	13	5.42	47	4.62
	Pet	15	5.45	10	4.29	8	2.96	9	3.75	42	4.13
	Shot	8	2.91	6	2.58	7	2.59	17	7.08	38	3.73
	Unknown	53	19.27	53	22.75	52	19.26	59	24.58	217	21.32
Final outcome	Captivity	112	40.73	85	36.48	32	11.85	49	20.42	278	27.31
	Died	67	24.36	47	20.17	75	27.78	54	22.50	243	23.87
	Euthanised	94	34.18	98	42.06	160	59.26	132	55.00	484	47.54
	Released	2	0.73	3	1.29	3	1.11	5	2.08	13	1.28
Total		**275**	**100.00**	**233**	**100.00**	**270**	**100.00**	**240**	**100.00**	**1018**	**100.00**



Supplementary information Fig. S3.2. Cause of admissions of vervet monkeys (a) annually and (b) monthly reported to an urban wildlife rehabilitation centre.

CHAPTER 4

Pregnancy complications in wild vervet monkeys in the urban mosaic landscape

Kerushka R. Pillay and Colleen T. Downs*

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

Formatted for *American Journal of Biological Anthropology: Brief Communication*

*** Corresponding Author:** Colleen T. Downs

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

Other Emails and ORCIDs:

K. Pillay Email: kerushka@gmail.com; ORCID: https://orcid.org/0000-0002-4018-783X

Running header: Pregnancy complications in wild vervet monkeys in suburbia

4.1 ABSTRACT

Objectives

The vervet monkey (*Chlorocebus pygerythrus*) is a widespread, typically seasonally breeding African primate. We report pregnancy complications in wild females in the urban mosaic landscape of Durban, South Africa, that required admittance to a wildlife rehabilitation centre.

Materials and methods

Through vervet monkey admission records, we detected dystocia, birthing complications, and retained placenta in pregnant females. We provide detailed medical information concerning the cause of admission, treatment, and outcome for each case.

Results

We found pregnancy complications in thirteen female vervet monkey adults and subadults, with most cases (69.2%) occurring in spring. Dystocia (difficult or obstructed labour) was the main cause of admission (46.2%), and in 69.2% of the cases, a veterinarian could attend to the animal. However, most cases of pregnancy complications resulted in death (86.6%).

Discussion

Evidence of dystocia in wild female vervet monkeys requires support for the management of parturition and medical assistance for delivery in wild primates in urban areas. Concerns about increased anthropogenic food causing increased birth size need further investigation.

Keywords: dystocia, human-wildlife conflict, birthing complications, parturition, vervet monkeys

4.2 INTRODUCTION

Parturition in mammals involves giving birth to live young through the pelvis (Brandt & Mitchell, 1971). Favourable conditions between the foetus and the maternal bony pelvis are required for safe and successful delivery (Schlabritz-Loutsevitch et al., 2018). However, as the foetus navigates through the birthing canal during parturition, several complications may arise that can result in maternal or neonatal morbidity or mortality (Kavanagh et al., 2011). Several factors can make parturition difficult, including weight of the neonate, large brain size, bipedalism, maternal condition and size and shape of the birth canal (Cunnane & Crawford, 2003; Wittman & Wall, 2007; Trevathan, 2015; Moffett, 2017; Pavličev et al., 2020). Additionally, the age and rank of a female may affect its ability to carry a foetus to full term (Turner et al., 1987). Dystocia refers to abnormal or difficult birth in delivery and includes maternal or foetal factors that can lead to death (Menon, 2016). Information on the birth processes of non-human primates is largely limited to captive populations (Trevathan, 2015). Previous reports of dystocia have been documented in captive non-human primates, namely in specific species: "she monkey" (Pandey et al., 2016), red-howler monkey (*Alouatta guariba clamitans*) (Daneze et al., 2016), pigtailed macaque (*Macaca nemestrina*) (Stockinger et al., 2011), and squirrel monkey (*Saimiri scireus*) (Favoretto et al., 2018). The study of dystocia and other birthing complications during parturition in the *Cercopithecus* species is limited.

The vervet monkey (*Chlorocebus pygerythrus*), hereafter vervet, is a semi-terrestrial, Old-World Cercopithecine monkey listed as Least Concern because of its widespread range and habitat types (Turner et al., 2016). The birthing season in the *Chlorocebus* genus varies geographically and is influenced by climate and food availability. For example, in South Africa, the gestation period for wild vervets is approximately 156-161 days, and births occur once a year between the

warmer, rainy season of September and February, depending on the availability of food (Isabell et al., 2013; Butynski & Jong, 2019). In captivity, however, species of the genus reproduce throughout the year (Seier, 2005; Isbell & Enstam-Jaffe, 2013). Females typically have their first infant between three and five years of age giving birth to one offspring per female, with twins rarely occurring (Fairbanks & McGuire, 1984; Bennett, 1988). Parturition in vervets is generally a solitary event at night while roosting in trees (Fairbanks & McGuire, 1984). It is challenging to witness actual birthing events as the process of parturition is quick and unpredictable in the wild. As such, it is often difficult to identify the mechanisms of birth in the wild.

Most studies on parturition in vervets have occurred in captive populations with access to veterinarian care (Fairbanks & McGuire, 1986; Seier et al., 2000; Kavanagh et al., 2011; Plant et al., 2020). This study describes novel evidence of birthing complications and dystocia observed in the parturition of wild vervets in the urban mosaic landscape of Durban, South Africa. Dystocia in wild vervets is uncommon and, to our knowledge, has not been documented.

Although there are no significant threats to vervets, urbanisation, habitat loss, and human-wildlife conflict compromise their welfare and mortality (Wimberger & Downs, 2010; Healy & Nijman, 2014; Chapman et al., 2016; Authors unpublished data). In urban mosaic landscapes with natural and managed green spaces, vervets are often considered a nuisance or trouble-causing animals because of their foraging behaviour and are often in direct contact with humans (Patterson et al., 2017; Thatcher et al., 2019). In South Africa, vervets are the most admitted mammal to rehabilitation centres, often leading to long-term captivity or death because of serious injuries (Wimberger & Downs, 2010; Healy & Nijman, 2014). Recent reports by the public witnessing possible birthing difficulties in female vervets in the urban mosaic landscape of Durban have emerged but were not formally documented (Supplementary Figure S4.1). Therefore, we

investigated birthing complications observed during the parturition of wild female vervets from the urban mosaic landscape requiring admittance to a wildlife rehabilitation centre.

4.3 MATERIAL AND METHODS

Data were collected as part of a long-term, retrospective study on vervet monkey admission records collated from the Centre for Rehabilitation of Wildlife (CROW), located in the central region of the eThekwini Municipality (-29.919527, 30.93627; Figure 4.1). This centre is the oldest wildlife rehabilitation centre in KwaZulu-Natal that assists with the rescue, rehabilitation, and release of injured, displaced or orphaned wildlife. Vervets that were rescued were brought in or reported to CROW by the public. CROW staff noted the date of intake, physical address of vervet rescue, cause of admission, sex, age class, initial treatment, and the outcome. From initial contact with the vervets, CROW staff did a physical inspection, and all observations made during and after the admission were documented under detailed medical notes (Table 4.1). Admissions termed "pregnancy complications" were evaluated from September 2012 to December 2018. The dates of intake were categorised by year, month, and season: spring (September-November), summer (December-February), autumn (March-May) and winter (June-August). The age classes of vervets were categorised as adult or subadult based on their external morphology and dental construct by CROW staff.

All pregnancy complications were classified into birthing complications, dystocia, and retained placenta. We defined birthing complications as females that were experiencing active birthing difficulties before the crowning of the foetus. Dystocia was defined when the foetus was stuck in the birth canal, and retained placenta described after labour when the placenta remained. The initial treatment was based on the individual case and extent of injury where vervets were

given medical treatment at CROW or sent to an external veterinarian for further treatment or were euthanised at CROW because the nature of injuries was too severe for survival. The case outcome was based upon whether the vervet was alive or dead after initial treatment. Vervets that were dead included those that were euthanised at admission or those that died naturally while under care.

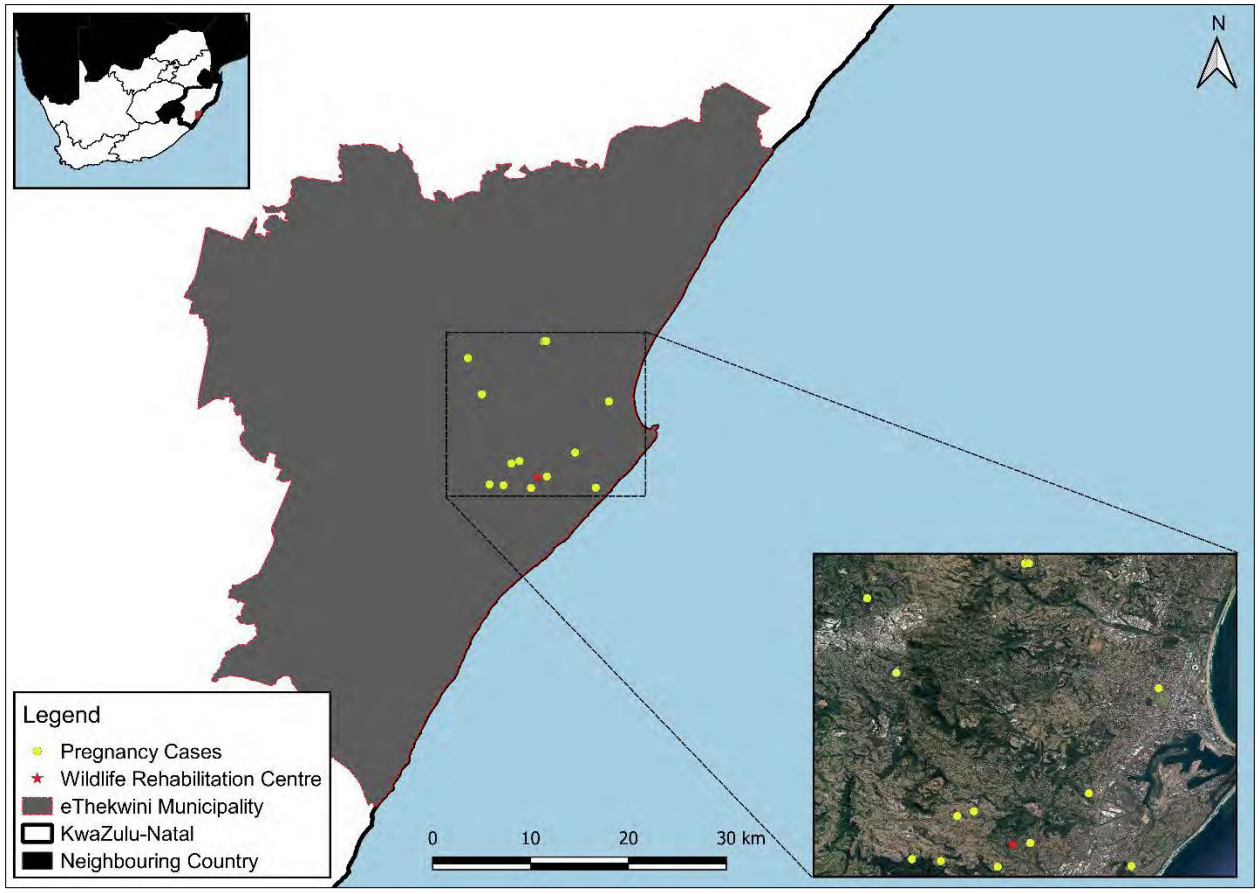


Figure 4.1 Pregnancy complications reported in female vervet monkeys (n = 13) in the urban mosaic landscape of Durban, eThekwini Municipality, KwaZulu-Natal Province, South Africa, from September 2012 to December 2018, requiring their admittance to a wildlife rehabilitation centre.

4.4 RESULTS

During the six-year study, thirteen pregnancy complications were described in wild female vervet monkeys at the wildlife rehabilitation centre (Table 4.1). No admittance data were reported for 2014 and 2016. In 2012, there was only one admission, and the year with the highest number of admissions was 2018, with six vervets admitted (Supplementary information Table S4.1). There was a marginal but steady increase in birthing complications over the year ($R^2 = 0.646$, $p = 0.101$, Figure 4.2). The scatterplot of standardised predicted values versus standardised residuals showed that the data met the assumptions of homogeneity of variance and linearity, and the residuals were approximately normally distributed.

The health condition of vervets was severe, with most cases displaying dystocia where a foetus was stuck in the birth canal (Table 4.1; Supplementary Figure S4.2). Other cases had septicaemia because of complicated births, or the womb did not heal. Generally (69.2%, $n = 9$), vervets with serious birthing complications were sent to a veterinarian, most (53.9%, $n = 7$) of which resulted in a caesarean section to remove the foetus.

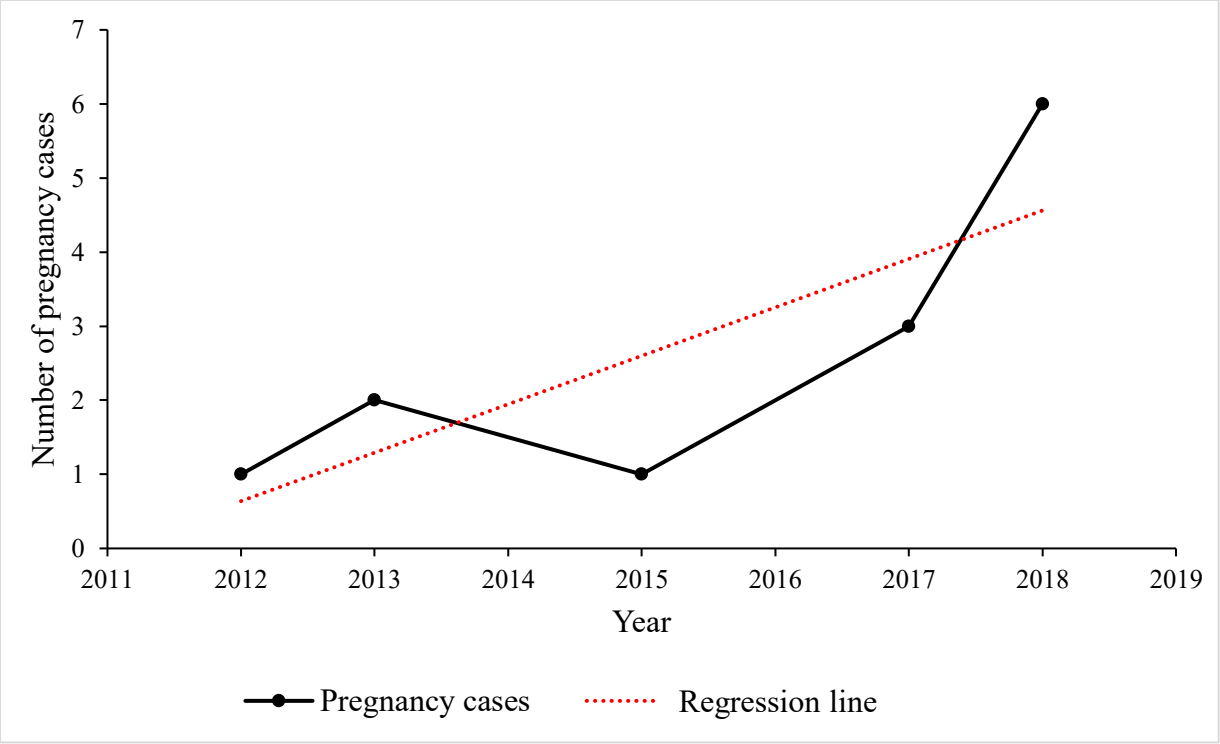


Figure 4.2 Summary of pregnancy cases with birthing complications in wild female vervets (*n* = 13) from an urban mosaic landscape requiring admittance to a wildlife rehabilitation centre between 2012 and 2018.

Table 4.1 Pregnancy complications in wild female vervets (n = 13) requiring admittance to a wildlife rehabilitation centre between 2012 and 2018.

Number	Date of intake	Month	Season	Age	Cause of admission	Initial treatment	Outcome of case	Medical notes
1	17/09/2012	September	Spring	Adult	Birthing complications	Medical treatment	Alive	Hernia. Female aborted baby. Cannot return only four monkeys left in troop. Kept at CROW.
2	08/08/2013	August	Winter	Adult	Retained placenta	Send to vet	Alive	Found on ground. Miscarriage & uterus infected. Cleaned vulva by vet, given antibiotics.
3	08/12/2013	December	Summer	Subadult	Dystocia	Euthanasia	Dead	Found female lying in garden, obstructive labour - baby stuck in birth canal & rotten.
4	29/10/2015	October	Spring	Adult	Dystocia	Send to vet	Dead	Pregnant & in obstructive labour. Removed dead baby at vet. Womb septic inside.
5	14/09/2017	September	Spring	Adult	Dystocia	Euthanasia	Dead	Very old female (no teeth) pregnant with stillborn baby stuck in birth canal. Did partial c-section as womb septic. Bite wounds covering body.
6	18/10/2017	October	Spring	Adult	Dystocia	Send to vet	Dead	Dead baby stuck half outside of female body - weak. Removed baby & put female on fluids at vet.
7	14/11/2017	November	Spring	Adult	Retained placenta	Send to vet	Dead	Weak female found in garden. Recently given birth but placenta still inside, no baby & wound to hind leg.
8	28/07/2018	July	Winter	Subadult	Birthing complications	Medical treatment	Dead	Very weak & lethargic female found in garden with some blood on pubic area - recently given birth. Died overnight.
9	24/09/2018	September	Spring	Adult	Birthing complications	Send to vet	Dead	Pregnant female, baby was removed by c-section but died very soon after.
10	25/09/2018	September	Spring	Adult	Dystocia	Send to vet	Dead	Female in labour, baby foot stuck out, body still in. C-section at vet, removed baby, died shortly after. Female had septicaemia.
11	01/10/2018	October	Spring	Adult	Birthing complications	Send to vet	Dead	Female in labour with suspected birthing difficulties. Baby removed by c-section, stillborn.
12	04/11/2018	November	Spring	Adult	Birthing complications	Send to vet	Dead	Pregnant with possible birthing complication. Baby removed by c-section but died soon after.
13	13/12/2018	December	Summer	Adult	Dystocia	Send to vet	Dead	Pregnant & in obstructive labour. Baby head crushed in labour, had to do c-section to remove dead baby.

* c-section – caesarean section

There was seasonal variation in pregnancy cases, with birthing problems highest in the austral spring (September-November) (69.2%, $n = 9$). Summer intake records were only for the month of December (15%, $n = 2$). Intake rates were lowest in winter (July-August) (15.4%, $n = 2$), and there were no intakes in autumn (Supplementary information Table S4.1). There was a statistical difference in the number of pregnancy cases reported in spring ($\chi^2 = 7.53$, df = 2, $p = 0.023$, Figure 4.3). Pregnancy complications originated from vervets displaying dystocia (46.2%, $n = 6$), birthing complications (38.5%, $n = 5$), and the retained placenta (15.4%, $n = 2$). The initial treatment of vervets with pregnancy complications was either to immediately send them to a veterinarian (69.2%, $n = 9$), give medical treatment (15.4%, $n = 2$), or were humanely euthanised (15.4%, $n = 2$). The veterinarian performed c-sections on females (54.0%, $n = 9$) that had neonates removed, that were either stillborn, stuck in the birth canal and/or dead, or alive but when removed died shortly after that. The outcome of females with pregnancy complications after treatment had more deaths (84.6%, $n = 11$) than alive vervets (15.4%, $n = 2$). There were no successful births from the female vervets admitted.

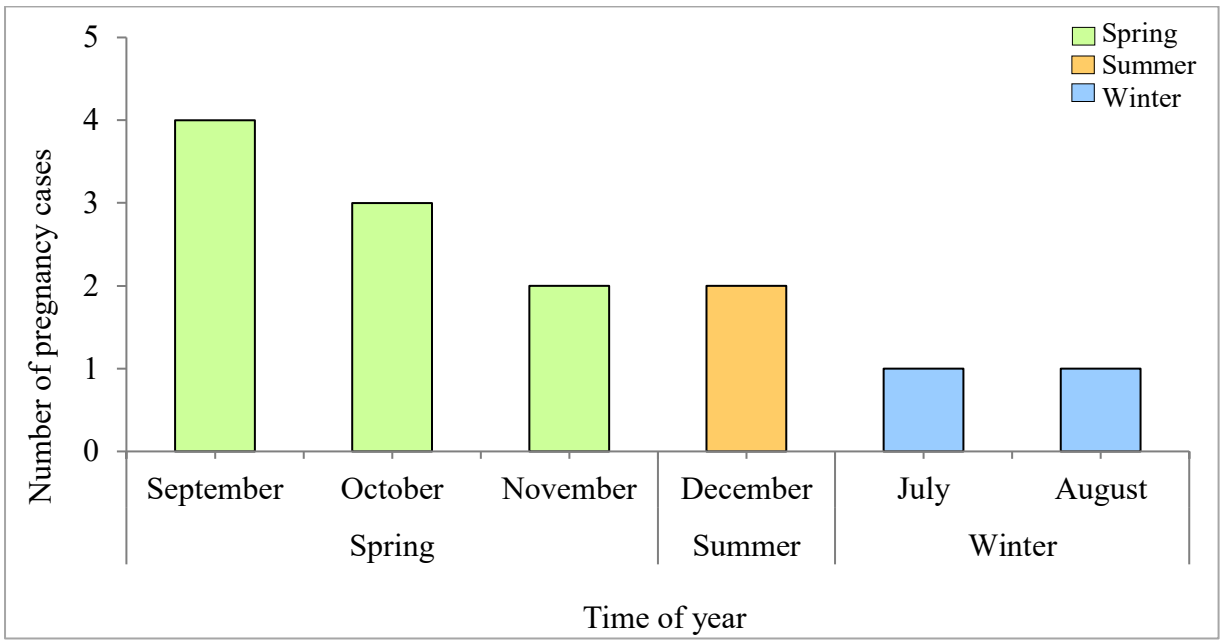


Figure 4.3 Pregnancy cases with birthing complications in wild female vervets ($n = 13$) during the time of year shown in months and seasons from 2012 to 2018 in the present study.

4.5 DISCUSSION

Generally, wild vervets are seasonal breeders usually giving birth when food is in abundance (Isbell & Enstam-Jaffe 2013; Botting 2020). In the Durban area, most births occurred in spring. Fewer pregnancy complications were reported in late winter and early summer in 2013 and 2018, respectively, maybe because of the changes in cyclic weather patterns because of unusual climate phenomena (Roberts, 2010; Campos et al., 2017; Van der Walt & Fitchett, 2020). These patterns could reflect seasonal receptivity of females because of seasonally mediated physiological changes coupled with food availability. Durban has a warmer and wetter climate in the summer and a much cooler, drier climate in the winter (SAWS, 2021). Furthermore, no cases were reported in the year 2014 and 2016, justifying the cyclic patterns explained by climate. These climatic changes could have affected birthing events of female vervets. The temperature and rainfall patterns could have also impacted vegetation growth leading to food scarcity and changes in breeding patterns (Lee, 1984; Lee & Hauser, 1998; McFarland et al., 2014). There were no reports of pregnancy events in autumn as food is generally scarce in the cooler, drier months and not the season for births (Turner et al., 2016).

Dystocia can be of maternal or foetal origin (Rodriguez et al., 2014), with the latter being the leading cause of pregnancy complications in this study. Dystocia is influenced by the number of previous births, gestational age, and the foetus's birth weight (Stockinger et al., 2011). The displacement of body parts obstructed in the birth canal led up to the asphyxiation of the foetus during parturition (Daneze et al., 2016). There were no successful births or neonates that survived the pregnancy complications reported in this study, even with the medical assistance provided. Primates can have difficulties during parturition because of cephalopelvic disproportion (Dubman et al., 2012; Trevathan, 2015). Female vervets with difficult or obstructed births can develop haemorrhages, peritonitis, intestinal torsion, and septicaemia from bacterial infections occurring primarily in the pelvis or uterus (Valverde &

Bicknese, 2021; Supplementary information Figure S4.2). Death can follow because of septic shock from sepsis developing because of the body's immune system response to infection (Valverde & Bicknese, 2021). The admitted vervets could have experienced excruciating pains because of the complications experienced during parturition, contrary to their relatively short, painless, and unassisted births previously documented (Lefebvre & Carli, 1985; Ebirim & Buowari, 2012). This could also explain the reason for high death rates.

The medical intervention for wild vervets experiencing birth complications was difficult as birth took place mostly at night as observed for diurnal primates (Jolly 1972; Bernis & Varea, 2012). Most vervets admitted needed further medical treatment whereby a veterinarian assisted with deliveries through caesarean sections. Although most vervets had adequate medical treatment, many had to be euthanised because their injuries were so severe that the animal could not recover.

Although the vervet is listed as “least-concern” on the IUCN Red List its population status is decreasing possibly because of increased urban infrastructure and human-wildlife conflict contributing to mortalities in the urban mosaic landscape of Durban (Wimberger & Downs, 2010; Healy & Nijman, 2014; Turner et al., 2016). Vervets are considered opportunistic omnivores but persistently portrayed as pest species because of their aggressive feeding behaviour to the proximity of human residences, and their use of anthropogenic food sources (Saj et al., 1999; Tournier et al., 2014; Chapman et al., 2016; Thatcher et al., 2020). Vervets often eat anthropogenic foods either through human provisioning or from food scraps in the urban landscape and have also shown flexibility in their feeding habits to persist in the urban landscape successfully (Loudon et al., 2014; Patterson et al., 2018; Downs et al., 2021). Increased anthropogenic high-sugar, high-fat diets could potentially have detrimental effects on their physiological condition and impact parturition (Fiori et al., 2013). An inadequate diet and lack of natural food have been associated with poor maternal conditions and high neonate

mortality rates (Hauser & Fairbanks 1988; Fairbanks & McGuire, 1995). Vervets are at risk of developing diabetes or being insulin resistant and hyperglycaemic, which may harm parturition (Kavanagh et al., 2011; Plant et al., 2020). Alternatively, increased anthropogenic food may result in increased foetal body masses. The female vervets in this study that had obstructed births can be attributed to heavier body mass of the foetus or poor body condition of females, both probably because of an increase in anthropogenic food sources in the urban mosaic landscape (Thompson et al., 2017; Pavličev et al., 2020; Thatcher et al., 2020).

4.6 CONCLUSIONS

Our study highlighted difficulties observed in the parturition of wild vervet monkeys in an urban mosaic landscape requiring admittance to wildlife rehabilitation centres in areas close to and some distance away from urban centres. Comprehensive data can be collated and collected from wildlife rehabilitation centres, providing an extensive use of realistic databases for wildlife studies. Scientists, animal welfare organisations, and veterinarians who work independently can provide valuable evidence for wildlife management through shared conservation efforts and reporting, as described here.

4.7 Acknowledgements

We are grateful to the Centre for Rehabilitation of Wildlife (CROW) for providing access to their admission records. Thanks to the CROW primate manager, Taylor Hawkins, and manager Clint Halkett-Siddall for their valuable insight on rescues. We are grateful to the CROW clinic staff, Sue-Ann Shutte and Estie Allan, for explanations of records and further discussion of medical and rehabilitation knowledge documented. The National Research Foundation (NRF) (ZA, Grant 98404), Durban Research Action Partnership (DRAP, ZA) and University of

KwaZulu-Natal (ZA) are thanked for their financial support. We thank K. Josiah for assistance with map work.

4.8 Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

4.9 References

Bennett, E.L. (1988). The occurrence of twins and accompanying behavioural changes in the banded langur, *Presbytis melalophos*. *Primates*, *29*, 557-563. https://doi.org/10.1007/BF02381142

Bernis, C., & Varea, C. (2012). Hour of birth and birth assistance: From a primate to a medicalized pattern? *American Journal of Human Biology*, 24, 14-21. https://doi.org/10.1002/ajhb.21228

Brandt, E.M., & Mitchell, G. (1971). Parturition in Primates: Behavior related to birth. In Rosenblum LA (Eds.), *Primate Behavior: Developments in Field and Laboratory Research 2* (pp.178-223). New York, USA: Academic Press.

Butynski, T.M., & De Jong Y.A. (2019) *Chlorocebus pygerythrus*. IUCN Red List Threat. Species, pp.e-T136271A17957823. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T136271A17957823.en

Campos, F. A., Morris, W. F., Alberts, S. C., Altmann, J., Brockman, D. K., Cords, M., ... & Fedigan, L. M. (2017). Does climate variability influence the demography of wild primates? Evidence from long-term life-history data in seven species. *Global Change Biology*, *23*, 4907-4921. http://doi.org/10.1111/gcb.13754

Chapman, C.A., Twinomugisha, D., Teichroeb, J.A., Valenta, K., Sengupta, R., Sarkar, D. and Rothman, J.M., 2016. How do primates survive among humans? Mechanisms employed by vervet monkeys at Lake Nabugabo, Uganda. In Ethnoprimatology (pp: 77-94). Springer, Cham. http://doi.org/10.1007/978-3-319-30469-4_5

Cunnane, S.C., & Crawford, M.A. (2003). Survival of the fattest: fat babies were the key to evolution of the large human brain. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, *136*, 17-26. http://doi.org/10.1016/S1095-6433(03)00048-5

Daneze, E.R., Penna, B.L., Marcondes, L.F., Léga-Palazzo, E. & Magalhães, G.M. (2016). Transverse lie with prolapsed arm in a female red-howler monkey (*Alouatta guariba clamitans*–Cabrera, 1940). *Journal of Medical Primatology*, *45*, 156-162. https://doi.org/10.1111/jmp.12218

Dubman, E., Collard, M., & Mooers, A. Ø. (2012). Evidence that gestation duration and lactation duration are coupled traits in primates. *Biology Letters*, *8*, 998-1001. https://doi.org/10.1098/rsbl.2012.0642

Ebirim, L. N., Buowari, O. Y. & Ghosh, S. (2012). Physical and psychological aspects of pain in obstetrics. In S.Ghosh (Eds.), *Pain in Perspective*. Intech Open Book Series. http://doi.10.5772/53923

Fairbanks, L.A. & McGuire, M.T. (1984) Determinants of fecundity and reproductive success in captive vervet monkeys. *American Journal of Primatology*, *7*, 27-38. https://doi.org/10.1002/ajp.1350070106

Fairbanks, L.A., & McGuire M.T. (1986). Age, reproductive value, and dominance-related behaviour in vervet monkey females: cross-generational influences on social relationships and reproduction. *Animal Behaviour*, *34*, 1710-1721. https://doi.org/10.1016/S0003-3472(86)80258-5

Fairbanks, L.A., & McGuire, M.T. (1995) Maternal condition and the quality of maternal care in vervet monkeys. *Behaviour*, 733-754. https://www.jstor.org/stable/4535296

Favoretto, S.M., Landy, E.C., Pereira, W.L.A., Castro, P.H.G., Imbeloni, A.A., Muniz, J.A.P., Santos, M.A., & Lacreta, A.C. (2018). Pelvimetry in Squirrel Monkeys (*Saimiri scireus* Linnaeus, 1758). *Pesquisa Veterinária Brasileira*, *38*, 767-772. https://doi.org/10.1590/1678-5150-PVB-5014

Fiori, J. L., Yu-Kyong S., Wook K., Krzysik-Walker S. M., González-Mariscal I., Carlson, O. D., Sanghvi M., et al., (2013) Resveratrol prevents β-cell dedifferentiation in nonhuman primates given a high-fat/high-sugar diet. *Diabetes*, *62*, 3500-3513. https://doi.org/10.2337/db13-0266

Hauser, M. D., & Fairbanks, L. A. (1988). Mother-offspring conflict in vervet monkeys: variation in response to ecological conditions. *Animal Behaviour*, *36*, 802-813. https://doi.org/10.1016/S0003-3472(88)80163-5

Healy, A., & Nijman, V. (2014). Pets and pests: vervet monkey intake at a specialist South African rehabilitation centre. *Animal Welfare*, *23*, 353-360. https://doi.org/10.7120/09627286.23.3.353

Isbell L & Enstam-Jaffe K. (2013). *Chlorocebus pygerythrus*, vervet monkey. In T. M. Butynski & J. Kingdon (Eds.), *Mammals of Africa* (pp. 277-283). London, GB: Bloomsbury.

Isbell, L.A. & Jaffe, K.E. (2013) *Chlorocebus pygerythrus* Vervet Monkey. In T.M. Butynski, J. Kingdon, & J. Kalina (Eds.), *The Mammals of Africa. Volume II: Primates* (pp. 277-283). London, UK: Bloomsbury Publishing.

Jolly, A. (1972). Hour of birth in primates and man. *Folia Primatologica*, *18*, 108-21. http://doi.org/10.1159/000155472

Kavanagh, K., Dozier B.L., Chavanne, T.J., Fairbanks, L.A., Jorgensen, M.J., & Kaplan, J.R. (2011). Fetal and maternal factors associated with infant mortality in vervet monkeys. *Journal of Medical Primatology*, *40*, 27-36. https://doi.org/10.1111/j.1600-0684.2010.00441.x

Kavanagh, K., Dozier, B. L., Chavanne, T. J., Fairbanks, L. A., Jorgensen, M. J., & Kaplan, J. R. (2011). Fetal and maternal factors associated with infant mortality in vervet monkeys. *Journal of Medical Primatology*, *40*, 27-36. http://doi:10.1111/j.1600-0684.2010.00441.x

Lee, P. C. (1984). Early infant development and maternal care in free-ranging vervet monkeys. *Primates*, *25*, 36-47. https://doi.org/10.1007/BF02382294

Lee, P. C., & Hauser, M. D. (1998). Long-term consequences of changes in territory quality on feeding and reproductive strategies of vervet monkeys. Journal of Animal Ecology, 347-358. https://www.jstor.org/stable/2647376

Lefebvre, L., & Carli, G. (1985). Parturition in non-human primates: pain and auditory concealment. *Pain*, *21*, 315-327. https://doi.org/10.1016/0304-3959(85)90161-7

Loudon, J. E., Grobler, J. P., Sponheimer, M., Moyer, K., Lorenz, J. G., & Turner, T. R. (2014). Using the stable carbon and nitrogen isotope compositions of vervet monkeys (*Chlorocebus pygerythrus*) to examine questions in ethnoprimatology. *PloS One*, *9*, 1-7, e100758. https://doi.org/10.1371/journal.pone.0100758

McFarland, R., Barrett, L., Boner, R., Freeman, N. J., & Henzi, S. P. (2014). Behavioral flexibility of vervet monkeys in response to climatic and social variability. *American Journal of Physical Anthropology*, *154*, 357-364. https://doi.org/10.1002/ajpa.22518

Memon M. A. (2016). Dystocia in Small Animals. In S.E. Aiello, M.A. Moses, D.G. Allen (Eds.), *The MSD Veterinary Manual* (MVM) (pp. 1-3325). Kenilworth, New Jersey, USA: Merck & Co. Inc.

Moffett, E.A., (2017). Dimorphism in the size and shape of the birth canal across anthropoid primates. *The Anatomical Record*, *300*, 870-889. https://doi.org/10.1002/ar.23572

Pandey, A.K., Gyan, S., Parveen, K., Sandeep, K., Sonu, K., Satbir S., Sarvan, K. & Davinder, S. (2016) Dystocia in a she monkey due to bilateral shoulder flexion: a rare case report. *Indian Veterinary Journal*, *93*, 61-62. http://ivj.org.in/downloads/57222pg%2...

Patterson, L., Kalle, R., & Downs, C.T. (2017). A citizen science survey: Perceptions and attitudes of urban residents towards vervet monkeys. *Urban Ecosystems, 20*, 617-628. https://doi.org/10.1007/s11252-016-0619-0

Patterson, L., Kalle, R., & Downs, C.T. (2018). Factors affecting presence of vervet monkey troops in a suburban matrix in KwaZulu-Natal, South Africa. *Landscape and Urban Planning*, *169*, 220-228. https://doi.org/10.1016/j.landurbplan.2017.09.016

Pavličev, M., Romero, R., & Mitteroecker, P. (2020). Evolution of the human pelvis and obstructed labor: new explanations of an old obstetrical dilemma. American Journal of Obstetrics and Gynecology, 222, 3-16. https://doi.org/10.1016/j.ajog.2019.06.043

Plant, M., Armstrong, C., Ruggiero, A., Sherrill, C., Uberseder, B., Jeffries, R., Nevarez, J., Jorgensen, M.J., Kavanagh, K. & Quinn, M.A. (2020). Advanced maternal age impacts physiologic adaptations to pregnancy in vervet monkeys. *GeroScience*, *42*, 1649-1661. http://doi.org/10.1007/s11357-020-00219-8

Plant, M., Armstrong, C., Ruggiero, A., Sherrill, C., Uberseder, B., Jeffries, R., ... Quinn, M. A. (2020). Impact of Advanced Maternal Age on Physiologic Adaptations to Pregnancy in Vervet Monkeys. bioRxiv. https://doi.org/10.1101/2020.04.06.027771

Roberts, D. (2010). Prioritizing climate change adaptation and local level resilience in Durban, South Africa. Environment and *Urbanization*, *22*, 397-413. https://doi.org/10.1177/0956247810379948

Rodriguez, J. S., Pearson L. K. & Tibary A. Parturition, N. (2014). Parturition and Obstetrics. In C. Cebra, D. E. Anderson, A. Tibary, R. J. Van Saun, L. W. Johnson (Eds.), *Llama and Alpaca Care: Medicine, Surgery, Reproduction, Nutrition, and Herd Health* (pp. 274-286). St. Loise, MO: Elsevier. https://doi.org/10.1016/B978-1-4377-2352-6.00024-9

Saj, T., Sicotte, P., & Paterson, J. D. (1999). Influence of human food consumption on the time budget of vervets. *International Journal of Primatology*, *20*, 977-994. https://www.academia.edu/13103483

SAWS, 2021. South African Weather Services, eThekwini Municipality – Durban Forecast. https://www.weathersa.co.za/

Schlabritz-Loutsevitch, N., Maher J., Sullivan R., Mari G., Schenone M., Cohen H. L., Word R. A., Hubbard G. B., & Dick E. J. (2018). Parturition in baboons (*Papio* spp.). Scientific Reports, 8, 1-6. http://doi.org/10.1038/s41598-018-19221-4

Seier J.V., Van Der Horst, G., De Kock M., & Chwalisz, K. (2000). The detection and monitoring of early pregnancy in the vervet monkey (*Cercopithecus aethiops*) with the use of ultrasound and correlation with reproductive steroid hormones. *Journal of Medical Primatology*, *29*, 70-75. https://doi.org/10.1034/j.1600-0684.2000.290204.

Seier, J. (2005) Vervet Monkey Breeding. In S. Wolfe-Coote (Eds.), *The Laboratory Primate* (pp. 175-179). Oxford, UK: Elsevier Academic Press.

Stockinger, D.E., Torrence, A.E., Hukkanen, R., Vogel, K.W., Hotchkiss, C.E., & Ha, J.C. (2011). Risk factors for dystocia in pigtailed macaques (*Macaca nemestrina*). *Comparative Medicine*, *61*, 170-175.

Thatcher, H. R., Downs, C. T., & Koyama, N. F. (2020). Understanding foraging flexibility in urban vervet monkeys, *Chlorocebus pygerythrus*, for the benefit of human-wildlife coexistence. *Urban Ecosystems*, *23*, 1349-1357. http://doi.org/10.1007/s11252-020-01014-1

Thatcher, H.R., Downs, C.T., & Koyama, N.F. (2019) Positive and negative interactions with humans concurrently affect vervet monkey (*Chlorocebus pygerythrus*) ranging behavior. *International Journal of Primatology*, *40*, 496-510. https://doi.org/10.1007/s10764-019-00099-6

Thompson, J. R., Valleau, J. C., Barling, A. N., Franco, J. G., DeCapo, M., Bagley, J. L., & Sullivan, E. L. (2017). Exposure to a high-fat diet during early development programs behavior and impairs the central serotonergic system in juvenile non-human primates. *Frontiers in Endocrinology*, *8*, 164. https://doi.org/10.3389/fendo.2017.00164

Tournier, E., Tournier, V., Van de Waal, E., Barrett, A., Brown, L., & Bshary, R. (2014). Differences in diet between six neighbouring groups of vervet monkeys. *Ethology*, *120*, 471-482. https://doc.rero.ch/record/287972

Trevathan, W. (2015) Primate pelvic anatomy and implications for birth. Philosophical transactions of the Royal Society of London. *Series B Biological Sciences*, *370*, 20140065. https://doi.org/10.1098/rstb.2014.0065

Turner, T., Hill, R., Coetzer, W.G., & Patterson, L, (2016). A conservation assessment of *Chlorocebus pygerythrus.* In M.F. Child, L. Roxburgh, E. Do Linh San, D. Raimondo & H.T. Davies-Mostert (Eds.), *The Red List of Mammals of South Africa, Swaziland and Lesotho* pp. 1-6. South Africa: South African National Biodiversity Institute and Endangered Wildlife Trust.

Turner, T.R., Whitten, P.L., Jolly, C.J. & Else, J.G. (1987) Pregnancy outcome in free-ranging vervet monkeys (*Cercopithecus aethiops*). *American Journal of Primatology*, *12*, 197-203. https://doi.org/10.1002/ajp.1350120207

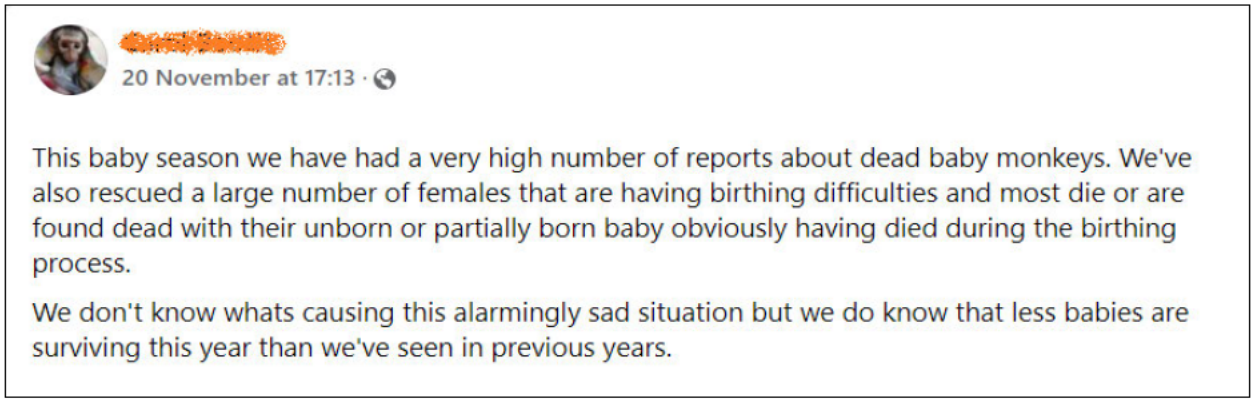
Valverde, C. R., & Bicknese, E. (2021). Primate Surgery. In R. A. Bennett & G. W, Pye (Eds.), *Surgery of Exotic Animals* (pp: 383-401). Wiley Online Library. https://doi.org/10.1002/9781119139614.ch24

Van der Walt, A. J., & Fitchett, J. M. (2020). Statistical classification of South African seasonal divisions on the basis of daily temperature data. *South African Journal of Science*, *116*, 1-15. http://dx.doi.org/10.17159/sajs.2020/7614

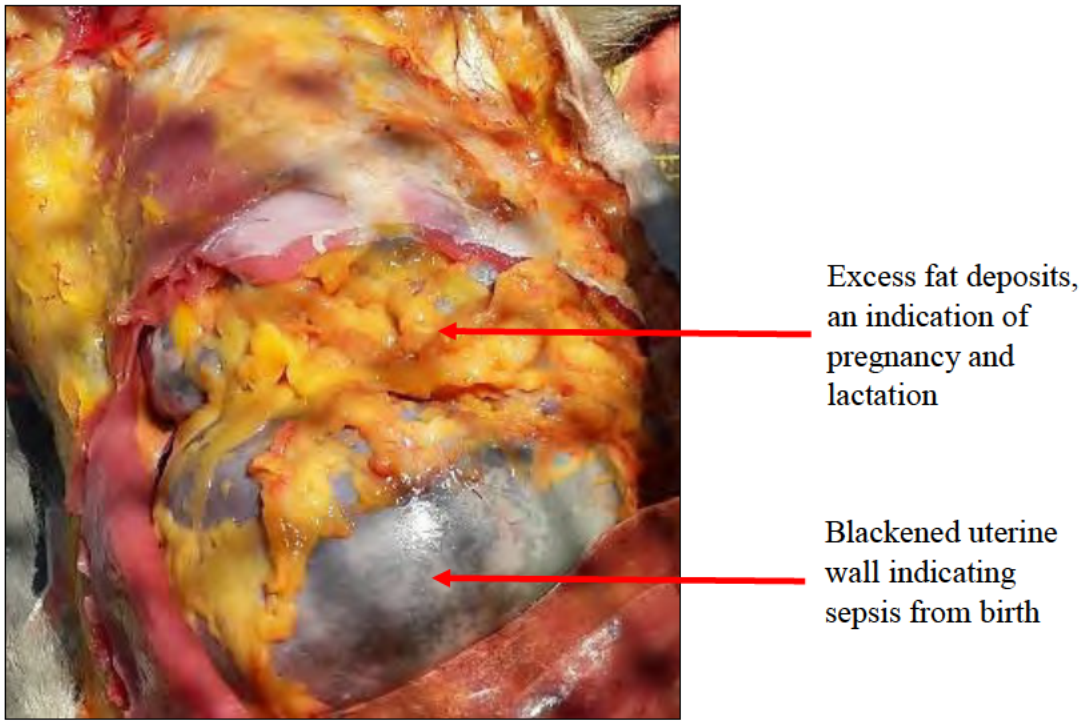
Wimberger, K., & Downs, C. T. (2010). Annual intake trends of a large urban animal rehabilitation centre in South Africa: a case study. *Animal Welfare*, *19*, 501-513.

Wittman, A.B., & Wall, L.L. (2007). The evolutionary origins of obstructed labor: bipedalism, encephalization, and the human obstetric dilemma. *Obstetrical & Gynecological Survey*, *62*, 739-748. http://doi.org/10.1097/01.ogx.0000286584.04310.5c

4.10 Supplementary information



Supplementary information Figure S4.1. Social media post from a member of public reporting sightings of birthing complications seen in female vervet monkeys in the eThekwini Municipality, KZN, SA. NB - the name is hidden to protect anonymity.



Supplementary information Figure S4.2. Necropsy showing an anterior view of the engorged abdominal region in an adult female vervet monkey that had recently given birth and was admitted to CROW in November 2017. NB - no neonate present at the time of rescue.

Supplementary information Table S4.1. Summary of female vervet pregnancy complications admitted to a wildlife rehabilitation centre in Durban, South Africa

Variable	Category	N	%	Total N	Total %
Year	2012	1	7.7	13	100.0
	2013	2	15.4		
	2015	1	7.7		
	2017	3	23.1		
	2018	6	46.2		
Season	Spring	9	69.2	13	100.0
	Summer	2	15.4		
	Winter	2	15.4		
Cause	Birthing complications	5	38.5	13	100.0
	Dystocia	6	46.2		
	Retained placenta	2	15.4		
Initial Treatment	Euthanasia	2	15.4	13	100.0
	Medical treatment	2	15.4		
	Send to vet	9	69.2		
Outcome	Alive	2	15.4	13	100.0
	Dead	11	84.6		

CHAPTER 5

Media framing of vervet monkeys: implications for human-wildlife interactions in South Africa

Kerushka R. Pillay and Colleen T. Downs*

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

Formatted for *Human Dimensions of Wildlife*

*** Corresponding Author:** Colleen T. Downs

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

Other Emails and ORCIDs:

K. Pillay Email: kerushka@gmail.com; ORCID: https://orcid.org/0000-0002-4018-783X

Running header: The media's influence on perceptions of vervet monkeys in South Africa

5.1 Abstract

Primates living along the urban mosaic landscape of suburbia result in increased human-wildlife interactions. One such conflict species is the abstruse vervet monkey, *Chlorocebus pygerythrus*. The portrayal of vervet monkeys in the media affects public perceptions, which can impact the overall protection of the species. We provide evidence from the first media content analysis on this conflict species from digital newspaper articles found in online news sources published between 1999 and 2020 in South Africa. We found a significant increase in the number of articles published under the main thematic frame directly impacting vervet monkeys than humans and reporting higher negative tones. Seven out of nine provinces published more articles on vervet monkeys with KwaZulu-Natal having significantly more articles than each of the other provinces. Human-vervet conflict had the highest recorded sub-frame themes with shooting and poisonings being the most published incidences. It is important to understand public opinion and their attitudes to regulate management and policy decisions to avoid negative persecution of vervet monkeys. The role of the media should be to create public awareness and feature positive articles that influence people to change their opinions on vervet monkeys and alleviate human-wildlife conflict.

Keywords: human-wildlife conflict, newspaper content analysis, public perceptions, vervet monkey

5.2 Introduction

Conservation and human-wildlife conflict issues surrounding primates have appeared globally in media outlets depicting both mutually positive and negative impacts on either individual (Distefano, 2005; Parathian et al., 2018; Goumas et al., 2020; Fernández et al., 2021; Estrada & Garber, 2022). These primates are often defined as “pests” because of their foraging behaviour near human-dominated landscapes (Hoffman & O'Riain, 2012a; Hill, 2017). For

instance, negative interactions arise between people and primates during crop-raiding events and these incidents are considered conflict (Hill et al., 2002; Siljander et al., 2020). Understanding and tackling human-wildlife conflict is often addressed through mass media since this is the most effective form of communication to the public at large (Gore & Knuth, 2009; Lyngdoh et al., 2017; Dayer et al., 2019).

The media play an important role in influencing the opinions and viewpoints that circulate within the public sphere (Christen & Gunther, 2003; Robinson, 2008; Cox, 2013). They serve as a key platform in which ideas are shared and where problems and challenges are openly discussed and debated (Lester, 2010; McCombs & Valenzuela, 2020). The dissolution of information through mass media engagements and their influence on public awareness, perceptions, and behaviour such as buying decisions and voting has now been well documented in the literature (Katz, 2001; Campbell et al., 2011; Brichacek, 2016; Gavin, 2018). Such studies provide researchers with a powerful tool that examines the effects of the media's role in influencing society's views and organising public opinion (Scheufele, 1999; Petty et al., 2009; Grasso et al., 2020). The methods applied by content analysis to mass media can determine trends in a systematic manner (Krippendorff, 2018). Content analysis is a classical method for qualitative research with a replicable and valid means for categories describing inferences from narrative material (Franzosi, 2008; Parry, 2019). It has been used multiple times in assessments of public media's communication of various wildlife information (Amiraslani & Dragovich, 2021). Previous studies of human-wildlife interactions of conflict species, analysed using media content analysis, include coyotes (Alexander & Quinn, 2008), leopards (Bhatia et al., 2013), sharks (Sabatier & Huveneers, 2018) and elephants (van Houdt et al., 2021).

National and international studies on human-wildlife interactions have portrayed the positive and negative associations of this interaction (Seoraj-Pillai & Pillay, 2017). In South

Africa, primate species have been well documented as conflict species (Chapman et al., 1998; Hoffman & O'Riain, 2012b; Mormile & Hill, 2017). Commonly, generalist primate species living near human-modified landscapes along the urban-forest mosaic showed higher frequencies of interactions in KwaZulu-Natal, South Africa (Patterson et al., 2018; Thatcher et al., 2019a). Urbanisation has led to habitat fragmentation leading to an increase in contact between people and primates that are often negatively persecuted because of the shared environment in which they occur (Lindshield, 2016; Thatcher et al., 2019b).

This research focused on contributions made by newspapers in shaping human-wildlife interactions (positive and negative) concerning vervet monkeys, *Chlorocebus pygerythrus*, in South Africa. These included attacks on humans, eating of people's food and monkeys being a threat in residential and farming areas (pers. comm.). The International Union for Conservation of Nature (IUCN) Red List of Threatened Species classifies vervet monkeys as "least concern" (Butynski & De Jong, 2019). According to IUCN, this means the species is unlikely to become extinct in the near future. In South Africa, the direct threats to vervet monkeys by humans are apparent but have not been documented in the scientific literature. The aim of this study was to provide content and styles of what ideas with respect to vervet monkeys have been reported in newspapers through media content analysis (Hill & Webber, 2010). Newspaper articles are attainable and contain in-text details, photographs and reflective writing by the author, and these data can be analysed statistically, unlike other forms of media reporting (Gheyle & Jacobs, 2017). Furthermore, newspaper articles are documented well over time and tracing back historical events is possible (Deacon, 2007). The purpose of this study was to determine the extent and nature of newspaper coverage of vervet monkeys in South Africa. The questions prompting this study were how visible South African primates are in the media, and particularly how vervet monkeys are portrayed in South African newspapers. The objective of the study was to conduct a content analysis of the nature of events related to vervet monkeys in South

Africa as portrayed by newspapers in online sources while highlighting the threat of anthropogenic activities to vervet monkeys in the urban mosaic landscape.

5.3 Methods

5.3.1 Data collection

The study included all available online newspaper articles published on vervet monkeys from 1999 to 2020. The sampling effort covered the period when online articles were easily available and accessible. No print articles were used in this study. We searched Google News Custom Search Engine API to include articles of online newspaper websites that contained the keywords 'vervet monkey' or '*Chlorocebus pygerythrus*' in either the title, the body of the article, figure captions and excluded all articles that contained the words "baboon" or any article irrelevant to the species. With every single hit of article relevant to vervet monkeys, we further searched terms within those specific newspapers' website search engines to include past or archived articles. The articles included topics reported by the newspaper, journalists, opinion letters, and letters to the editors written by members of the public. All these articles were scanned for relevance and to identify those which addressed issues related to vervet monkeys in South Africa. Only articles that referred to vervet monkeys within the South African context were included. We reviewed all articles identified through the search and excluded all non-relevant articles not pertaining to vervet monkeys. We included repeated stories if they were in a different newspaper source. A total of 322 vervet monkey-related articles were obtained from the searches, which were then selected for media content analysis and coding. Duplicates were removed. All articles were read, and common categories were noted at first. We recorded data on general article information: date, publication, newspaper, location, number of words, number of photographs and number of vervet monkeys published in the article. The data were further grouped into the year, months and seasons and location was grouped spatially according

to province. Framing for content analysis was conducted on the newspaper articles, coding the material for quantitive analysis. The full summary codes, descriptions and keywords are explained in Table 5.1. The main thematic frame (the main thought), sub-frame (secondary thought) and framing tone (positive, negative, or neutral) were coded for each article. Additionally, the main organisation or group mentioned in the article and/or any solutions provided were also coded for further interpretation. To determine the human-vervet interactions in both vervet monkeys and humans, we analysed and grouped the sub-frames further into direct interactions of vervet monkeys directly causing conflict on humans or the latter of humans causing conflict against the vervet monkeys. We reported on the direct interactions of vervet monkeys and humans based on keywords extracted during the content analysis and reported this as human-vervet conflicts (Table 5.1).

5.3.2 Statistical analyses

In this study, we applied content analysis to extract wildlife conservation-related topics from articles with vervet monkeys and public comments implicating vervet monkeys. Responses were coded and aggregated thematically, and percentage (%) data were generated from the coded information. Descriptive statistics, including frequency analyses, were undertaken. A two-way ANOVA examined the effect of article frame and article tone on the number of words in an article. We also compared data using Pearson chi-square to identify differences between comparison groups. All statistical analyses were performed using IBM SPSS Statistics 27.0 (IBM, Armonk, USA), reporting the means ± SE were appropriate and set with a probability of < 0.05 to denote significance.

Table 5.1 Summary of codes, descriptions and keywords used for the content analysis of articles on vervet monkey articles featured in online South African newspapers from 1999 to 2020 in the present study.

Content analysis	Code	Description and keywords from articles	N	%
Main thematic frame	Direct impact: *humans*	Blogs, opinion/letters to editors, farming, feeding by people, fundraising for rehabilitation centres/sanctuaries, humans attacked by vervets, information articles, prevention and how to avoid conflict, rehabilitation centres that help vervets in distress, research on vervets, property visits, nuisance by vervets	140	42.17
	Direct impact: *vervet monkeys*	Attacked by dog, albino, animal cruelty, declining population, dispersing, electrocution, habitat loss, hairless monkey, hunting, kept as pet, muthi/witchcraft, motor vehicle accident, orphan, painted, poisoning, shooting, twins	192	57.83
Sub-frames (Main topics)	Anti-vervet	Articles depicting vervets as perpetrators and people as victims. Crop damage, property damage, stealing food, attacking people, children, pets	32	9.64
	Pro-vervet	Articles informing and educating on how to deal, live, coexist with vervets. Informative or facts regarding vervet behaviour, prevention of conflict with vervets, research on vervets, rehabilitation centres assisting vervets, rehabilitation centres fundraising for vervets	63	18.98
	Opinion	Articles written by people. Blogs, opinion/letters to editors	45	13.55
	Human-vervet conflict (HVC)	Articles depicting vervets as victims and humans as perpetrators. Attacked by dog, animal cruelty, declining population, dispersing, electrocution, habitat loss, hunting, kept as pet, muthi/witchcraft, motor vehicle accident, orphan, painted, poisoning, shooting	189	56.93
	Natural	Articles displaying natural phenomena i.e., albino monkey, hairless monkey, twins born	3	0.90
Tone	Positive	Vervet was alive after rescue, rehabilitation, and/or released back to the wild, given a second chance, coexisting, or enjoying vervets around, person convicted against animal abuse	61	18.37
	Negative	Vervets attacked, shot, maimed, tied, strike, knocked, electrocuted, abused, injured and/or killed, resulting in pain, torture, or death. Also included human context of vervet attacks, bit or scratched, people, children, pets	167	50.30
	Neutral	Ambiguous, no impact on man, no impact on vervet. Neither promoting nor rejecting a side for or against the situation	104	31.33
Organisation	WRC	Wildlife Rehabilitation Centre - any rehab/sanctuary centre dealing with wildlife or animals	53	15.96
	PRC	Primate Rehabilitation Centre - any rehab centre/sanctuary dealing specifically with primates or vervets only	120	36.14
	NSPCA	The National Council for Societies for the Prevention of Cruelty to Animals (NSPCA) & local SPCAs	43	12.95
	GA	Government Authority - all provincial departments, any government entity, all State-Owned Entities (SOEs)	23	6.93
	Other	Members of public, conservancy, private security group, newspaper journalist, veterinarians, researcher	93	28.01
Solution	Legal	Law enforcement, lay criminal charges, legislation, firearm control act, SAPS, reported to authorities, policies, asking for tip-offs, released with warming, petition, monetary rewards	66	19.88
	RRR	Rescue, and/or Rehabilitation, and/or Release (RRR), and/or euthanasia, confiscate, catch, capture, relocate, foster, vet services, by rehabilitation centre	93	28.01
	Education	Human intervention through learning, coexistence, research, informing, don't feed, managing waste	86	25.90
	Other	Impacting vervets directly, culling, population control, birth control, feeding stations, feeding, donations to rehabilitation centres to keep them operational	22	6.63
	None	No additional information provided leading to a solution or recommendation	65	19.58

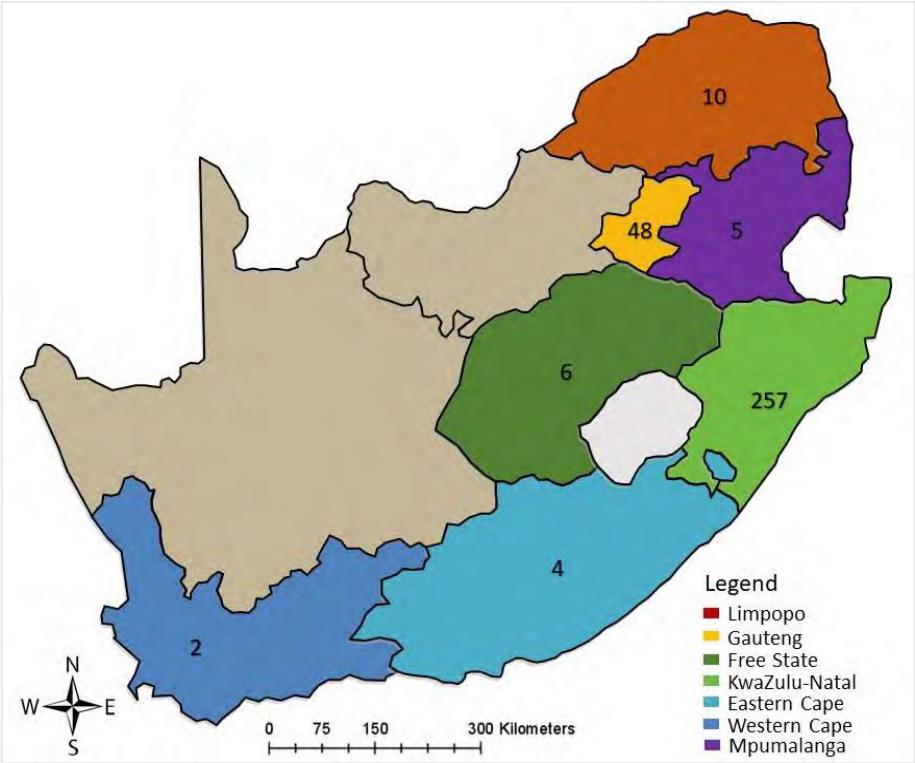


Figure 5.1. Total number of media reports (n = 332) per province published on vervet monkeys from 1999 to 2020 in newspapers from South Africa.

5.4 Results

5.4.1 Trends of newspaper articles

We found no newspaper articles referring to vervet monkeys dating earlier than 1998. We analysed the content of 332 vervet monkey newspaper articles from various newspaper sources/brands of newspapers in South Africa from October 1999 to December 2020 (Figure 5.1, Table 5.3). We found that the number of vervet monkey articles was relatively low from 2000 to 2010 and increased exponentially after that (Figure 5.2a). The mean annual number of newspaper articles was 16.60 (± 4.51) and increased significantly during the study period (R^2 = 0.633, F (1,19) = 31.079, $p < 0.05$, Figure 5.2a). No newspaper articles reported on vervet monkeys in 2009-2010, and the highest number (n = 67) was in 2017 (Figure 5.2a). The mean monthly reported newspaper articles were 27.67 (± 2.18) and differed significantly (χ^2 (11) = 22.578, $p < 0.05$), Figure 5.2b). Although we observed seasonal trends in newspaper articles

[spring (23.80%, n = 79), summer (23.19%, n = 77), autumn (30.72%, n = 102), winter (22.29%, n = 74)], we found no significant difference with season (χ^2 (3) = 5.952, p = 0.114, Figure 5.2b). The number of articles published was significantly higher in KwaZulu-Natal than in other provinces in South Africa (χ^2 (6) = 1112.994, p = 0.114, Table 2, Figure 5.1). The organisations that were mainly featured in articles were significantly higher for Primate Rehabilitation Centres (χ^2 (4) = 93.241, p = 0.114, Table 5.1) than all the other organisations reported. There were significant differences for solutions provided in newspaper articles with rescue-rehabilitation-release (RRR) as the highest recorded solution (χ^2 (4) = 93.241, p = 0.114, Table 5.1). The total number of words reported in newspaper articles was 55030 and the total number of photographs published was 152. The mean number of words and photographs published in articles was 382.92 (± 12.50) (range: 48-1913), and 1.23 (± 0.07) (range: 1-10), respectively.

Table 5.2 Total vervet monkey newspaper articles published in the different provinces of South Africa from 1999 to 2020 in the present study.

Province	**N**	**%**
Eastern Cape	4	1.2
Free State	6	1.8
Gauteng	48	14.5
KwaZulu-Natal	257	77.4
Limpopo	10	3.0
Mpumalanga	5	1.5
Western Cape	2	0.6

Table 5.3 Total number of vervet monkey articles published in respective South African newspapers from 1999 to 2020 in the present study.

No	Newspaper	N	%
1	IOL News	47	14.2
2	Northglen News	45	13.6
3	Highway Mail	30	9.0
4	South Coast Herald	24	7.2
5	Southlands Sun	20	6.0
6	Daily News	19	5.7
7	North Coast Courier	18	5.4
8	Zululand Observer	17	5.1
9	South Coast Sun	16	4.8
10	Berea Mail	11	3.3
11	TimesLIVE	9	2.7
12	Benoni City Times	9	2.7
13	The Citizen	7	2.1
14	News24	7	2.1
15	Lowvelder	5	1.5
16	The Mercury	3	0.9
17	Fourways Review	3	0.9
18	Letaba Herald	3	0.9
19	The Witness	3	0.9
20	Midrand Reporter	3	0.9
21	Krugersdorp News	2	0.6
22	Kempton Express	2	0.6
23	Sunday Tribune	2	0.6
24	Polokwane Review and Polokwane Observer	2	0.6
25	Knysna-Plett Herald	2	0.6
26	Rosebank Killarney Gazette	2	0.6
27	Chatsworth Rising Sun	2	0.6
28	Pretoria Rekord	2	0.6
29	Vryheid Herald	1	0.3
30	Northern Natal News	1	0.3
31	Fin24	1	0.3
32	Brakpan Herald	1	0.3
33	Cape Town etc	1	0.3
34	Roodepoort Record	1	0.3
35	North Coast Rising Sun	1	0.3
36	African Reported	1	0.3
37	The Daily Maverick	1	0.3
38	Sandton Chronical	1	0.3
39	The Star	1	0.3
40	Capital Newspapers	1	0.3
41	Mail & Guardian	1	0.3
42	Cape Times	1	0.3
43	Boksburg Advertiser	1	0.3
44	Bedfordview & Edenvale News	1	0.3
45	Randburg Sun	1	0.3
	Total	**332**	**100.0**

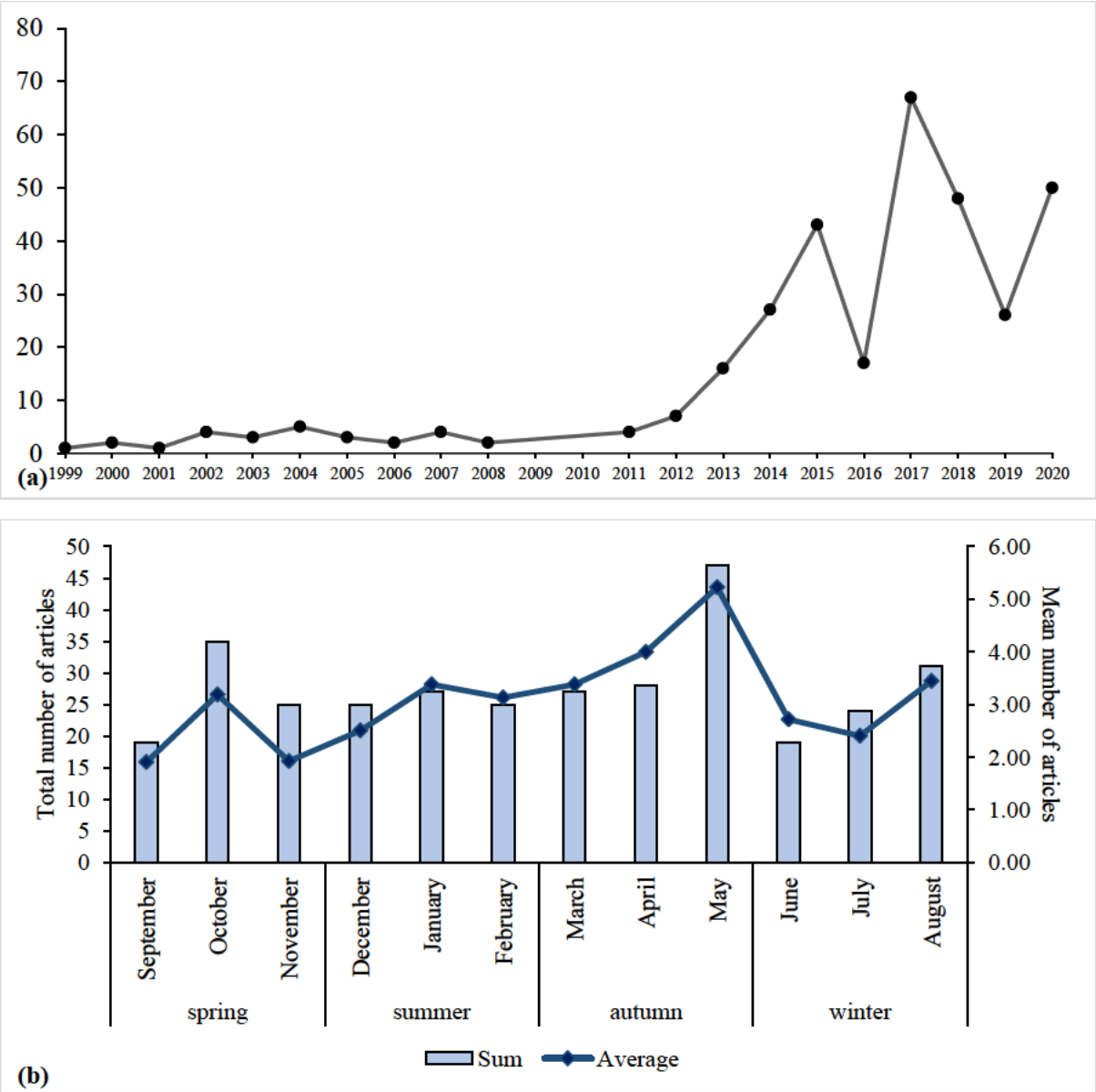


Figure 5.2 Total number of articles (n = 332) published on vervet monkeys from 1999 to 2020 from online newspapers in South Africa, showing how the number of articles varied (a) per year and (b) per month and season.

5.4.2 Frames and tone of newspaper articles

The main thematic frames revealed a higher number of articles framed on the direct impact of vervet monkeys (57.8%, n = 192) rather than on humans (42.2%, n = 140, Table 5.4). There were significant differences in sub-frames reported in newspaper articles (χ^2 (4) = 311.795, p

< 0.05) and were highest for human-vervet conflict (HVC) (56.9%), followed by pro-vervet (19.0%), opinion (13.6%), anti-vervet (9.6%) and the least for natural cases (0.9%) (Table 1). There were greater negative tones (50.3%) than neutral tones (31.3%) and positive tones (18.4%) when reporting on the tone of newspaper articles. Overall, there were significant differences between the tone and main thematic frames reported in newspaper articles (χ^2 (2) = 73.875, $p < 0.05$, Table 5.4, Fig 5.4). We examined the effect of article frame and article tone on the number of words in an article. There was no statistically significant interaction between the effects of the main thematic frame and tone on the number of words (two-way ANOVA, F (5, 326) = 0.233, $p = 0.793$, Figure 5.5).

Table 5.4. Summary of tone and frame reported in vervet monkey articles from 1999 to 2020 in the present study.

	Frame					
	Vervet monkey impact		Human impact		Total	
Tone	**N**	**%**	**N**	**%**	**N**	**%**
Negative	128	38.5	39	11.8	167	50.3
Neutral	25	7.5	79	23.8	104	31.3
Positive	39	11.8	22	6.6	61	18.4
Total	192	57.8	140	42.2	332	100.0

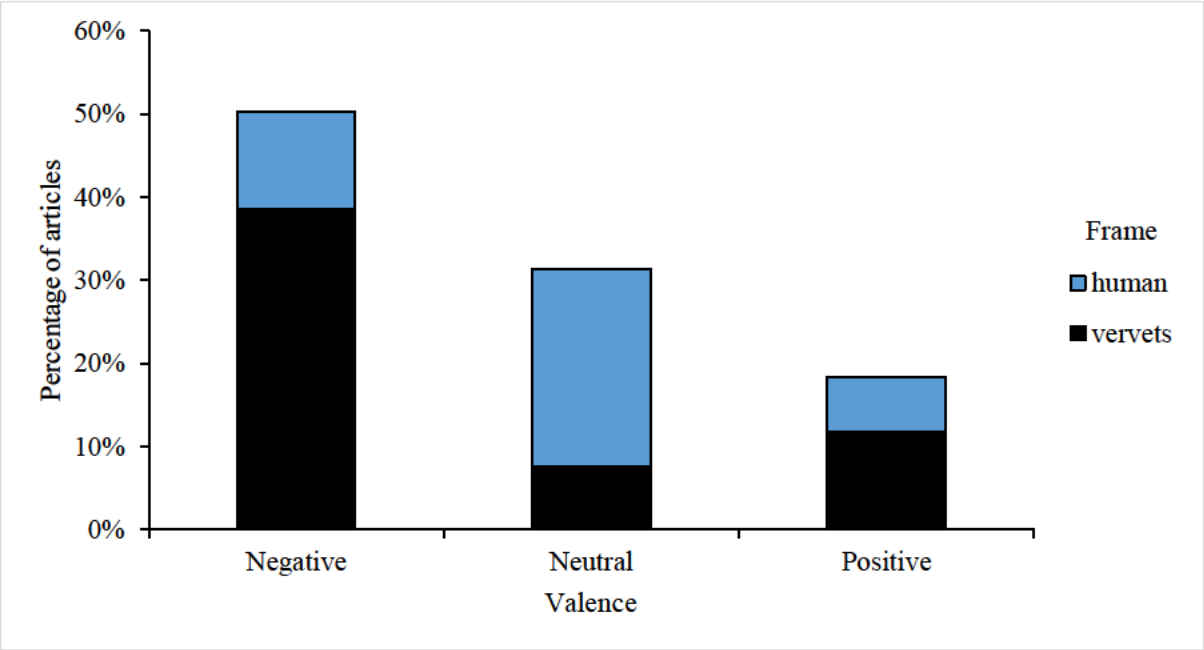


Figure 5.3 Percentage tone reported in vervet monkey articles grouped by main thematic frame from 1999 to 2020 in online newspapers in South Africa.

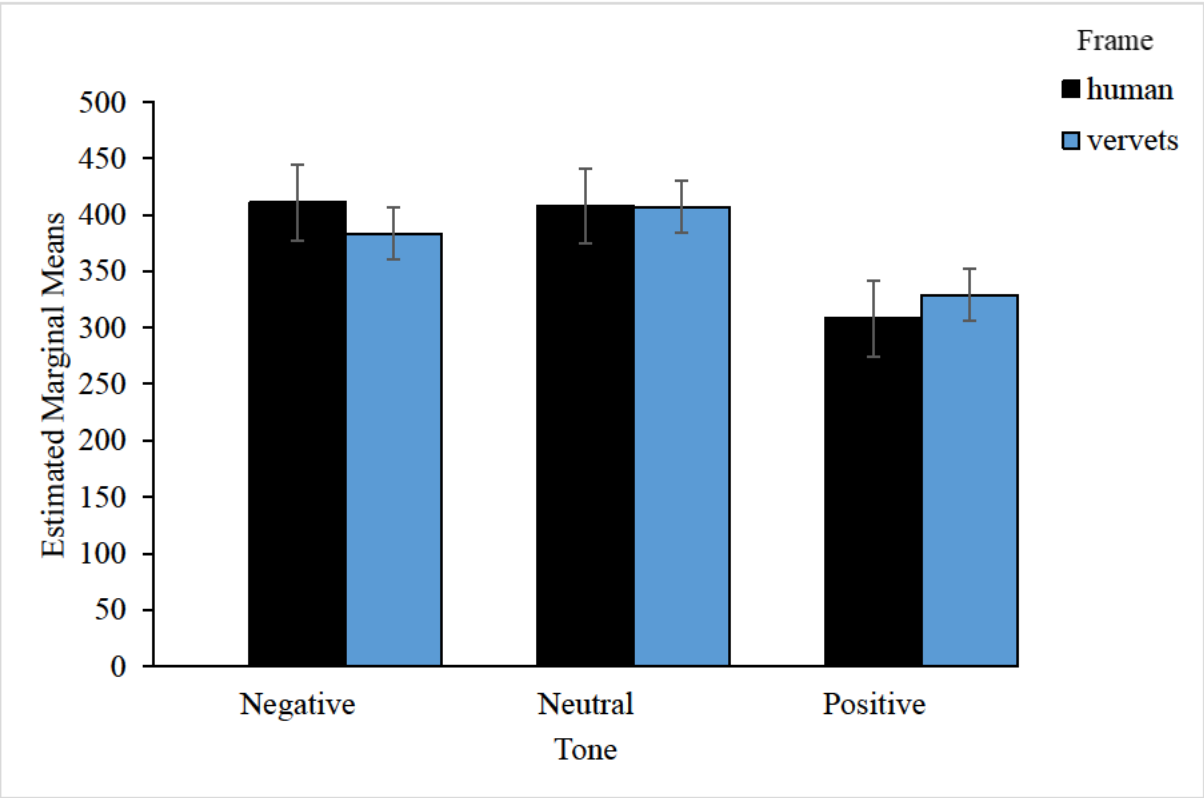


Figure 5.4 Estimated marginal means (± SE) and the effect of main thematic frames and tone on the number of words reported in an article.

5.4.3 Human-vervet monkey interactions published in newspaper articles

The newspaper articles recorded in this study accounted for 2105 individual vervet monkeys, 78 troops and 20 reported under the term "several". Of the 192 main thematic framed articles on vervet monkeys, there were 17 direct threats on vervet monkeys by humans (Table 5.5). Many (66.7%, n = 128) articles reported negative interactions between humans and vervet monkeys and included graphic photographs (Figure 5.3). These were significantly higher than the articles on neutral (13.0%, n = 25) and positive (20.3%, n = 39) interactions of humans and vervet monkeys (χ^2 (2) = 97.531, $p < 0.05$). The highest three recorded direct threats across newspaper articles were shooting, animal cruelty, and poisoning (Table 5.5, Figure 5.6). The direct threats on vervet monkeys were mostly negatively toned, with the highest reported articles from the province of KwaZulu-Natal (Figure 5.6). Autumn also had the highest reported articles, and solutions were mainly from the legal category (Table 5.5, Figure 5.6). Other recorded human-vervet conflicts included dispersing individuals, habitat loss, motor vehicle accidents, vervet monkeys kept as pets, and painted vervet monkeys. Single conflict events observed and reported included a hairless vervet monkey, an albino vervet monkey, vervet monkey twins born and a single article on declining population (Table 5.5, Figure 5.6).

The main thematic framed articles on humans (n = 140) comprised of nine direct interactions with humans by vervet monkeys (Table 5). Newspaper articles were significantly higher for neutral interactions (56.4%, 79), rather than negative (27.9%, n = 39) and positive interactions (15.7%, n = 22) between humans and vervets (χ^2 (2) = 36.700, $p < 0.05$). Most direct interactions for human-vervet conflict were reported on public opinions, rehabilitation centres, informative pieces, and human attacks. There were less than 10 cases reported for vervet monkeys as a nuisance, for prevention, feeding, fundraising and research (Table 5.5).

Figure 5.5 Selected photographs displaying human-vervet conflict (HVC) in online media newspaper sources in South Africa with permission from the news media sources.

Table 5.5. Human-vervet conflict (HVC) published in vervet monkey newspaper articles (*n* = 332) from 1999 to 2020 in the present study.

Human-vervet conflict	***n***	**%**	**Vervet-human conflict**	***n***	**%**
Shooting	57	29.7	Public opinion	45	32.1
Animal cruelty	28	14.6	Rehabilitation centres	28	20.0
Poisoning	17	8.9	Informative	19	13.6
Dispersing	15	7.81	Human attacks	12	8.6
Habitat loss	12	6.3	Nuisance	10	7.1
MVA	10	5.2	Prevention	10	7.1
Kept as pet	10	5.2	Feeding	9	6.4
Painted monkey	10	5.2	Fundraising	5	3.6
Hunting	10	5.2	Research	2	1.4
Muthi/witchcraft	6	3.1			
Orphan	6	3.1			
Electrocution	4	2.1			
ABD	3	1.6			
Hairless monkey	1	0.5			
Albino	1	0.5			
Twins	1	0.5			
Declining population	1	0.5			
Total	**192**	**100.0**		**140**	**100.0**

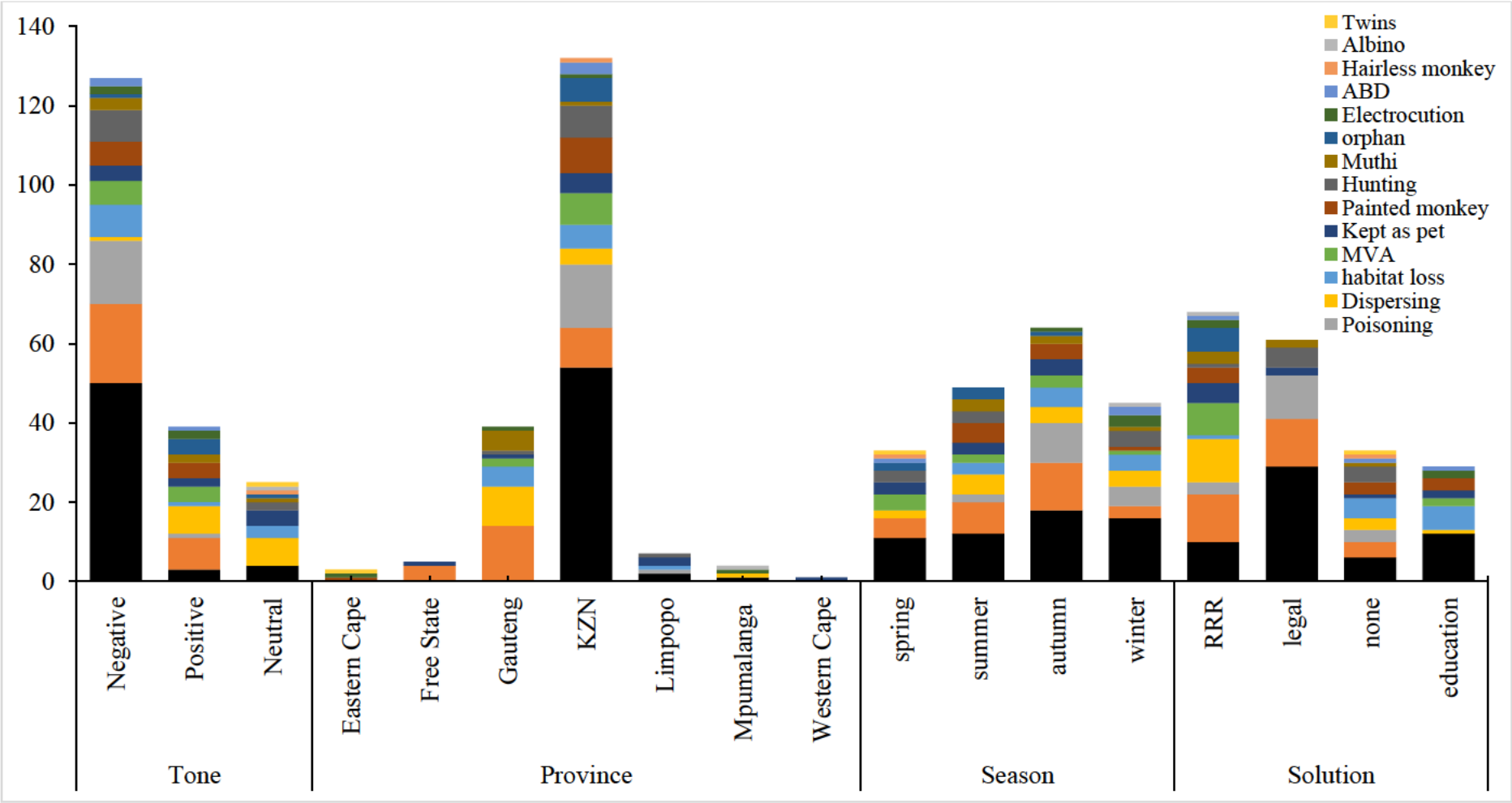


Figure 5.6 Human-vervet monkey conflicts reported in online media newspaper sources in South Africa grouped by tone, provinces, season, and solutions.

5.5 Discussion

Due to the power of media, public perceptions of vervet monkeys and interactions associated with human-wildlife conflict can be influenced by how newspapers portray these events. We analysed the articles using pre-determined codes to determine what and how vervet monkey news was reported and found a significant increase in published online newspaper articles over the period of 21 years. The sudden increase in online newspaper articles describes the increase of online users prompting journalists to report on stories regarding negative human-vervet conflict, which is meant to cause panic in society. This study revealed that vervet monkeys appeared in the news as early as two decades ago, albeit at a relatively low frequency. The frequency with which they appear in articles has spiked since the early 2010s. This increase can be linked to the rise of the internet prompting digital journalism and a greater number of newspapers going online than print media (Boczkowski, 2005). Additionally, newspapers can be archived with technological advancements and unlimited space on the world wide web. More people can access online newspapers on their cellphones allowing information to disseminate across the world easily and effortlessly. Additionally, we observed ebbs and flows in the records during certain years. Similar results were obtained for coyotes (Alexander & Quinn, 2011) and grey wolves (Delibes-Mateos, 2020), and this may be because of other news taking precedence over vervet monkeys at the time.

There were no published articles in the years 2009 and 2010. During this time, the FIFA World Cup was held in South Africa and dominated the media in terms of infrastructure development, social, economic and tourism, largely portraying news optimistically (Alegi, 2008; Saayman & Rossouw, 2008; Harris, 2011). Events like these are prioritised for the benefit of people and the economy without considering the impacts it has on biodiversity and wildlife. The growing human population coupled with infrastructure development and the demand to fulfil human needs result in wildlife habitat destruction (DeFries et al., 2004). In

KwaZulu-Natal Province, the increase in habitat fragmentation and alterations to the natural landscape as a result of urbanisation is said to account for a dramatic (45%) reduction of green space by the year 2050 (Jewitt et al., 2015). The loss of pristine habitats for vervet monkeys is also reducing, resulting in a greater concentration of troops in smaller patches and increasing interactions between these primates and people living on the periphery of the urban-forest mosaic interface (Thatcher et al., 2019b). The increasing number of articles published from KwaZulu-Natal showed this. Even though interactions between vervet monkeys and people are substantial, vervet monkeys seem to be persisting as the remaining forest patches support their biological needs in the anthropogenic landscape (Zungu et al., 2020). Although the province of Gauteng contains the smallest area in size, with the highest density of people (Compaan et al., 2017), vervet monkey presence was still prevalent in this human-dominated and fragmented area as observed from online news sources in the region. The urban-rural mosaic occurs in Gauteng, especially in areas abutting neighbouring rural provinces.

Reuters Institute Digital News Report found that 91% of South Africans use online sources as a medium to follow the news, allowing greater dissemination of information (Newman et al., 2021). Media framing of vervet monkeys dominated online news in South Africa. The publishing of articles directly impacting vervet monkeys was significantly higher than human-related articles involving vervet monkeys, advocating for the media's consistency in reporting unbiased and fair stories (Singer, 2010). Journalists distinctively captured the human-wildlife interactions documented in this study to highlight the plight of vervet monkeys in the country. However, this can create disproportionate attention creating an emotive response of fear, panic, sadness, or anger in the public sphere (Lunney & Moon, 2008). Furthermore, sensationalising topics evoked debates among the community at large, especially after broadcasting malicious stories implicating vervet monkeys, causing greater publishing of several opinionated and editorial articles at the time. The sentiments of people on the topic of

vervet monkeys were either pro or anti-monkey and this filtered through their interactions with the species. With no effect on the number of words written in articles, the publications on whether articles were framed around vervet monkeys or humans were nearly equal in length, indicating an equal standing in the journalism context (Phillips, 2014).

The overall tone of online newspaper articles was largely negative because most publications were framed on topics of human-vervet conflict implicating humans as the offender. There were negative implications around vervet monkeys causing conflict to people, but this was relatively low. In contrast, there was a fair amount of neutrally toned articles reflecting people's beliefs and who did not take a stance on either "for or against" the conflict issue. There were positive outcomes for vervet monkeys reported, but this was relatively low and mostly reported when humans intervened to assist a distressed vervet monkey. Apart from media sources generally profiting from "bad news" (Iggers, 2018), the publication of both negative and positive interactions between vervet monkeys and people further implies that a human-wildlife problem does exist (Arbieu et al., 2021).

Human-vervet conflicts featured in online newspaper articles were portrayed negatively, similarly observed in other conflict species that interact closely with people, like beavers (*Castor canadensis*) (Destefano & Deblinger, 2005), black bears (*Ursus americanus*) (Gore et al., 2005), and Californian sea lions (*Zalophus californianus*) (Purdy, 2015). When human-wildlife interactions turn negative, then a conflict situation arises (Buijs & Jacobs, 2021). Vervet monkeys move in search of food, foraging close to private gardens and crops, rummaging through rubbish bins, often causing indirect damage to properties. The grotesque acts of conflict by people on vervet monkeys were intentional and often brought on by retaliatory or retributive harm because of the aforementioned behaviour (Humle & Hill, 2016). These heinous incidences, including shooting and poisoning, were the most common in this study and KwaZulu-Natal. In South Africa, shooting wildlife and discharging a firearm in an

urban area are criminal offences and cause immediate pain and suffering if the individual is shot (Pickover, 2005). Poisoning of any wildlife, including vervet monkeys, is illegal, lethal, and destructive to the ecosystem as a whole (Sillero-Zubiri & Switzer, 2001).

Animal cruelty and dispersing individuals were reportedly the highest in Gauteng. Since vervet monkeys do not naturally occur abundantly in this area, people often kept them in private zoos and cages while neglecting their welfare (animal cruelty), and some individual vervet monkeys often escaped and moved into unfamiliar ranges (dispersing). Additionally, we found seasonal trends in the autumn months, as this period is important for dispersing males of vervet monkeys (Young et al., 2019). Natural food availability is generally low in the cooler months of the year, which forces vervet monkeys to forage on artificial food resources to supplement their diet and close to human settlements (Thatcher et al., 2020). In Gauteng, they usually supplement their diet with anthropogenic food even during the height of summer. Females also require a high nutrient-rich diet to support them before the birthing season, which approaches early spring and summer (Lee & Hauser, 1998; McFarland et al., 2014). People take exception to vervet monkeys foraging near their homes, as highlighted in these online sources. Vervet monkeys need to be in absolute proximity for people to inflict direct injury or harm. Habitat loss of vervet monkeys also drives them to move into a shared landscape. Other human-vervet conflicts included the painting of monkeys as a myth to "chase away the troop" if one looks like an outcast (Lee & Priston, 2005) and the stoning and burning of any individual vervet monkey that roamed into the informal settlements because it was "bewitched". The effects of anthropogenic activities were evident but low and were reported as collisions with motor vehicles, orphaned babies, kept as pets, electrocutions, and attacked by dogs. The main conflict arising from vervet monkeys on humans was caused by nuisance or physical attacks on people, children or pets, which were overall low.

The impact of primate and wildlife rehabilitation centres, the NSPCA and other concerned groups were beneficial to vervet monkeys in terms of support for human-vervet conflict. These organisations provided rescue, relief, refuge, and advocacy for this conflict species. There was no definitive solution for addressing human-vervet conflict in the media but reported resolutions included the rescue, rehabilitation, and release (RRR) of injured vervet monkeys, education on coexistence and applying the legal environmental framework to ensure crimes committed against vervet monkeys are strengthened. Although rehabilitation centres seem effective in supporting human-vervet conflict, a common trend was seeking donations from the public to support the operational costs of the organisation to assist wildlife in rehabilitation. We also noted that during the establishment years, rehabilitation centres were in trouble with the law and government authorities for operating as sanctuaries and keeping vervet monkeys in cages on their residential properties without permits. By law in South Africa, no person is allowed to keep wildlife without permits (Cousins et al., 2010). Guidelines on the rehabilitation of vervet monkeys include the immediate release of vervet monkeys into the wild instead of long-term captivity (Guy et al., 2014; Guy et al., 2015). The number of reported vervet monkeys in online newspapers amounted to > 2105, including the unknown size of troops. We could not quantify the survival or mortality events of vervet monkeys, so the impact on wild populations is uncertain. When considering primates as humans closest living ancestors, it is devastating when people deliberately hurt or maim any wildlife. This study showed that negative perceptions reported on vervet monkeys in the media are common, exacerbating their status as "pest" species. We need to shift the paradigm of public perceptions and media framing to include more effective solutions such as education and proper waste management.

Finally, there were many reported incidences and disturbing images of animal abuse recorded in this study (Figure 5.6). Despite the numerous cases of ill-treatment of vervet

monkeys by people, the enforcement of the current laws regulating the welfare of wild animals is lacking. Often very rarely do these make it through the justice system. The Animals Protection Act 71 of 1962, which the NSPCA of South Africa enforces, is presently the primary national law regulating animal welfare and is used in many domestic animal abuse cases. Regarding wild animal welfare, particularly relevant to vervet monkeys, a notable case resulted in the successful conviction in a magistrate's court of Dr Alfreda Alberts, a veterinarian from Dunnottar, Nigel, Gauteng Province. The incident dates to 2012 and involved a vervet monkey with three of its legs severed and an open abdomen. The matter took eight years to come to fruition, but finally, in 2020, the National Prosecuting Authority secured the conviction. Although such a conviction was welcomed, the penalty imposed of around ZAR 10 000.00 suspended for three years ridicules the severity of the offence. The lack of fair sentencing does not deter others from committing similar offences or shooting, abusing, and poisoning wildlife, as we have found reoccurrences in online newspapers. Therefore, we suggest harsher sentencing and support by government authorities to enforce stricter policies and legislation on the crimes committed against all wildlife to avoid local extinction of the species along the urban mosaic landscape of South Africa. Additionally, vervet monkey persecution is a welfare issue primarily and needs further support.

The media has generally negatively framed vervet monkeys in this study, further allowing people to abuse and disrespect the species. Since the media plays an active role in how society views certain aspects, journalists should promote and reinforce optimistic stories and educational pieces on how to live with the species. There is a need to change the reporting style to support conservation efforts and promote the overall welfare of the species. This will also assist with reporting animal cruelty to the relevant bodies for intervention and promote the wellbeing and survival of the vervet monkey.

5.6 Conclusions

In summary, this study is the first attempt to use media content analysis to document human-wildlife conflict in a common generalist primate in South Africa. The dissemination of various news reporting mediums remains central to how people receive information about the world, their surroundings, the environment and, in this case, the frequency of wildlife interactions. This study has provided useful insights into online news communications published on vervet monkeys between 1999 and 2020. During the Anthropocene era, there is continued urbanisation leading to increased interactions of vervet monkeys and troops in a shared environment. Major findings of this study reveal that human-vervet conflict exists and is increasing annually in the urban mosaic landscape in KwaZulu-Natal, reporting the highest incidences of newspaper articles. Our findings provide evidence for improving legislation for vervet monkeys in the hope that environmental agencies and policymakers can adequately conserve the species through stronger enforcement. Future studies can explore international trends and include the effects of all media coverage communications such as social media, scientific reports, radio and television broadcasts on vervet monkeys and human interactions regarding the human-vervet conflict. This will provide sufficient support to promote coexistence rather than conflict in future reporting as well as prevent the further spread of negative perceptions around vervet monkeys living in suburbia. Ultimately media reports create awareness, and hopefully, this leads to acceptance of vervet monkeys by the public, and support might follow consequently.

5.7 Acknowledgements

We thank the National Research Foundation (NRF) (ZA, Grant 98404) and Durban Research Action Partnership (DRAP) for their financial support.

5.8 References

Alegi, P. (2008). 'A nation to be reckoned with': the politics of World Cup stadium construction in Cape Town and Durban, South Africa. *African Studies, 67*(3), 397-422.

Alexander, S. M., & Quinn, M. S. (2008). *Human-coyote (Canis latrans) interaction in Canadian urban parks and green space: Preliminary findings from a media-content analysis*. Paper presented at the Canadian Parks for Tomorrow, Canada.

Alexander, S. M., & Quinn, M. S. (2011). Portrayal of interactions between humans and coyotes (*Canis latrans*): Content analysis of Canadian print media (1998-2010). *Cities and the Environment, 4*(1), 1-24.

Amiraslani, F., & Dragovich, D. (2021). Wildlife and newspaper reporting in Iran: A data analysis approach. *Animals, 11*(6), 1487. https://doi.org/10.3390/ani11061487

Arbieu, U., Chapron, G., Astaras, C., Bunnefeld, N., Harkins, S., Iliopoulos, Y., . . . Mueller, T. (2021). News selection and framing: the media as a stakeholder in human-carnivore coexistence. *Environmental Research Letters, 16*(6), 1-10. https://doi.org/10.1088/1748-9326/ac05ef

Bhatia, S., Athreya, V., Grenyer, R., & Macdonald, D. W. (2013). Understanding the role of representations of human-leopard conflict in Mumbai through media-content analysis. *Conservation Biology, 27*(3), 588-594.

Boczkowski, P. J. (2005). Digitizing the news: Innovation in online newspapers. mit Press.

Brichacek, A. (2016). Six ways the media influence elections. *University of Oregon School of Journalism and Communication (Online News Page)*.

Buijs, A., & Jacobs, M. (2021). Avoiding negativity bias: Towards a positive psychology of human-wildlife relationships. *Ambio, 50*(2), 281-288.

Butynski, T. M., & De Jong, Y. A. (2019). *Chlorocebus pygerythrus*. *The IUCN Red List of Threatened Species*, 1-9. doi:DOI:10.2305/IUCN.UK.2008.RLTS.T136271A4267738.en

Campbell, R., Martin, C. R., & Fabos, B. (2011). *Media and culture: An introduction to mass communication*. Macmillan.

Chapman, K. L., Lawes, M. J., & Macleod, M. M. (1998). Evaluation of non-lethal control methods on problematic samango monkeys in the Cape Vidal Recreation Reserve, greater St. Lucia Wetland Park. *South African Journal of Wildlife Research, 28*(3), 89-99.

Christen, C. T., & Gunther, A. C. (2003). The influence of mass media and other culprits on the projection of personal opinion. *Communication Research, 30*(4), 414-431.

Compaan, P. C., Whittington-Jones, C. A., Engelbrecht, I., Dumalisile, L., Mills, L., Pfab, M. F., . . . Nevhutalu, L. S. (2017). The Gauteng Conservation Plan: Planning for biodiversity in a rapidly urbanising province. *Bothalia-African Biodiversity & Conservation, 47*(1), 1-16.

Cousins, J. A., Sadler, J. P., & Evans, J. (2010). The challenge of regulating private wildlife ranches for conservation in South Africa. *Ecology and Society, 15*(2), 1-22. doi:https://www.jstor.org/stable/pdf/26268142.pdf

Cox, R. (2013). *Environmental communication and the public sphere*: Sage.

Dayer, A. A., Williams, A., Cosbar, E., & Racey, M. (2019). Blaming threatened species: Media portrayal of human–wildlife conflict. *Oryx, 53*(2), 265-272.

Deacon, D. (2007). esterday's papers and today's technology: Digital newspaper archives and 'push button'content analysis. *European Journal of Communication, 22*(1), 5-25.

DeFries, R. S., Foley, J. A., & Asner, G. P. (2004). Land-use choices: Balancing human needs and ecosystem function. *Frontiers in Ecology and the Environment, 2*(5), 249-257.

Delibes-Mateos, M. (2020). Wolf Media Coverage in the Region of Castilla y León (Spain): Variations over Time and in Two Contrasting Socio-Ecological Settings. *Animals, 10*(4), 1-12. doi:10.3390/ani10040736

Destefano, S., & Deblinger, R. D. (2005). Wildlife as valuable natural resources vs. intolerable pests: a suburban wildlife management model. *Urban Ecosystems, 8*(2), 179-190.

Distefano, E. (2005). Human-Wildlife Conflict worldwide: collection of case studies, analysis of management strategies and good practices. *Food and Agricultural Organization of the United Nations* 1-34. doi:http://www.fao.org/documents

Estrada, A., & Garber, P. A. (2022). Principal drivers and conservation solutions to the impending primate extinction crisis: Introduction to the special issue. *International Journal of Primatology*, *15*, 1-14. https://doi.org/10.1007/s10764-022-00283-1

Fernández, D., Kerhoas, D., Dempsey, A., Billany, J., McCabe, G., & Argirova, E. (2021). The current status of the world's primates: Mapping threats to understand priorities for primate conservation. *International Journal of Primatology*, 43, 15-39. https://doi.org/10.1007/s10764-021-00242-2

Franzosi, R. (2008). Content analysis: Objective, systematic, and quantitative description of content. *Content Analysis, 1*(1), 21-49.

Gavin, N. T. (2018). Media definitely do matter: Brexit, immigration, climate change and beyond. *The British Journal of Politics and International Relations, 20*(4), 827-845.

Gheyle, N., & Jacobs, T. (2017). Content Analysis: a short overview. *Internal Research Note*, 1-17. Retrieved from https://www.researchgate.net/profile/Niels-Gheyle/publication/321977528_Content_Analysis_a_short_overview/links/5a3bee680f7e9b10e23bb2f9/Content-Analysis-a-short-overview.pdf

Gore, M. L., & Knuth, B. A. (2009). Mass media effect on the operating environment of a wildlife-related risk-communication campaign. *Journal of Wildlife Management, 73*(8), 1407-1413.

Gore, M. L., Siemer, W. F., Shanahan, J. E., Schuefele, D., & Decker, D. J. (2005). Effects on risk perception of media coverage of a black bear-related human fatality. *Wildlife Society Bulletin, 33*(2), 507-516.

Goumas, M., Lee, V. E., Boogert, N. J., Kelley, L. A., & Thornton, A. (2020). The role of animal cognition in human-wildlife interactions. *Frontiers in Psychology, 11*, 3019.

Grasso, C., Lenzi, C., Speiran, S., & Pirrone, F. (2020). Anthropomorphized nonhuman animals in mass media and their influence on human attitudes toward wildlife. *Society & Animals, 1*(aop), 1-25.

Guy, A. J., Curnoe, D., & Banks, P. B. (2014). Welfare based primate rehabilitation as a potential conservation strategy: does it measure up? *Primates, 55*(1), 139-147.

Guy, A. J., Curnoe, D., & Stone, O. M. (2015). Assessing the release success of rehabilitated vervet monkeys in South Africa. *South African Journal of Wildlife Research, 45*(1), 63-75.

Harris, L. (2011). Mega-events and the developing world: A look at the legacy of the 2010 Soccer World Cup. *South African Journal of International Affairs, 18*(3), 407-427.

Hill, C., Osborn, F., & Plumptre, A. J. (2002). *Human-Wildlife Conflict: Identifying the problem and possible solutions*. Retrieved from New York (USA):

Hill, C. M. (2017). Primate crop feeding behavior, crop protection, and conservation. *International Journal of Primatology, 38*(2), 385-400.

Hill, C. M., & Webber, A. D. (2010). Perceptions of nonhuman primates in human–wildlife conflict scenarios. *American Journal of Primatology, 72*(10), 919-924.

Hoffman, T. S., & O'Riain, M. J. (2012a). Landscape requirements of a primate population in a human-dominated environment. *Frontiers in Zoology, 9*(1), 1-17.

Hoffman, T. S., & O'Riain, M. J. (2012b). Monkey management: using spatial ecology to understand the extent and severity of human-baboon conflict in the Cape Peninsula, South Africa. *Ecology and Society, 17*(3), 1-16.

Humle, T., & Hill, C. (2016). People-primate interactions: implications for primate conservation. In: Wich, S. A. & Marshall, A. J. (Eds.), *An Introduction to Primate Conservation*. Oxford: Oxford University Press, pp. 219-240.

Iggers, J. (2018). *Good news, bad news: Journalism ethics and the public interest* (1st ed.). New York, USA: Routledge.

Katz, E. (2001). Media effects. In: Smelser, N. J. & Baltes, P. B. (Eds.), *International Encyclopedia of the Social & Behavioral Sciences.* Oxford: Pergamon, pp. 9472-9479.

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*: Sage publications.

Lee, P. C., & Hauser, M. D. (1998). Long-term consequences of changes in territory quality on feeding and reproductive strategies of vervet monkeys. *Journal of Animal Ecology*, *67*, 347-358.

Lee, P. C., & Priston, N. E. C. (2005). Human attitudes to primates: perceptions of pests, conflict and consequences for primate conservation. In: Paterson, J.D. & Wallis, J. (Eds.), *Commensalism and conflict: The human-primate interface Vol 4*. American Society of Primatologists, pp.1-23.

Lester, L. (2010). *Media and environment: Conflict, politics and the news*: Polity.

Lindshield, S. M. (2016). Protecting nonhuman primates in peri-urban environments: A case study of Neotropical monkeys, corridor ecology, and coastal economy in the Caribe Sur of Costa Rica. In: Waller, M. T. (Ed.). *Ethnoprimatology : Primate Conservation in the 21st Century*. Cham: Springer International Publishing, pp. 351-369.

Lunney, D., & Moon, C. (2008). The portrayal of human-wildlife interactions in the print media. In: Lunney, D., Munn, A., & Meikle, W. (Eds.), *Too close for comfort: contentious issues in human-wildlife encounters*. Mosman, NSW, Australia: Royal Zoological Society of New South Wales, pp. 52-64.

Lyngdoh, S., Dixit, D., & Sinha, B. C. (2017). Print mass media coverage of wildlife in the developing world. *Current Science, 113*(4), 564-570. doi:https://www.jstor.org/stable/26293887

McCombs, M., & Valenzuela, S. (2020). *Setting the agenda: Mass media and public opinion*: London: John Wiley & Sons.

McFarland, R., Barrett, L., Boner, R., Freeman, N. J., & Henzi, S. P. (2014). Behavioral flexibility of vervet monkeys in response to climatic and social variability. *American Journal of Physical Anthropology, 154*(3), 357-364.

Mormile, J. E., & Hill, C. M. (2017). Living with urban baboons: Exploring attitudes and their implications for local baboon conservation and management in Knysna, South Africa. *Human Dimensions of Wildlife, 22*(2), 99-109.

Newman, N., Fletcher, R., Schulz, A., Andi, S., Robertson, C. T., & Nielsen, R. K. (2021). South Africa. In R. I. f. t. S. o. Journalism (Ed.), *Reuters Institute Digital News Report 2021* (10th ed.). Oxford: University of Oxford, pp. 158-159.

Parathian, H. E., McLennan, M. R., Hill, C. M., Frazão-Moreira, A., & Hockings, K. J. (2018). Breaking through disciplinary barriers: human-wildlife interactions and multispecies ethnography. *International Journal of Primatology, 39*(5), 749-775.

Parry, K. (2019). Quantitative Content Analysis. *The SAGE Handbook of Visual Research Methods*, pp. 353.

Patterson, L., Kalle, R., Downs, C. T. (2017). A citizen science survey: Perceptions and attitudes of urban residents towards vervet monkeys. *Urban Ecosystems, 20,* 617-628. https://doi.org/10.1007/s11252-016-0619-0

Patterson, L., Kalle, R., & Downs, C. T. (2018). Factors affecting presence of vervet monkey troops in a suburban matrix in KwaZulu-Natal, South Africa. *Landscape and Urban Planning, 169,* 220-228. https://doi.org/10.1016/j.landurbplan.2017.09.016

Petty, R. E., Brinol, P., & Priester, J. R. (2009). Mass media attitude change: Implications of the elaboration likelihood model of persuasion. In: Bryant, J., & Zillmann, D. (Eds.), *Media Effects: Advances in Theory and Research.* London, UK: Routledge, pp. 141-180.

Phillips, A. (2014). *Journalism in context: Practice and theory for the digital age* (1st ed.). London, UK: Routledge.

Pickover, M. (2005). *Animal Rights in South Africa*. Cape Town, South Africa: Juta and Company Ltd.

Purdy, C. (2015). Barking News Story: Media Perceptions of the California Sea Lion. *California Digital Library*, pp. 1-29.

Robinson, P. (2008). The role of media and public opinion. In: Smith, S., Hadfield, A., & Dunne, T. (Eds.), *Foreign policy: theories, actors, cases*. Oxford: University of Oxford, pp. 137-154.

Saayman, M., & Rossouw, R. (2008). The economic value of the 2010 Soccer World Cup. *Acta Commercii, 8*(1), 1-14.

Sabatier, E., & Huveneers, C. (2018). Changes in media portrayal of human-wildlife conflict during successive fatal shark bites. *Conservation and Society, 16*(3), 338-350.

Scheufele, D. A. (1999). Framing as a theory of media effects. *Journal of Communication, 49*(1), 103-122.

Seoraj-Pillai, N., & Pillay, N. (2017). A meta-analysis of human-wildlife conflict: South African and global perspectives. *Sustainability, 9*(1), 34.

Siljander, M., Kuronen, T., Johansson, T., Munyao, M. N., & Pellikka, P. K. E. (2020). Primates on the farm-spatial patterns of human-wildlife conflict in forest-agricultural landscape mosaic in Taita Hills, Kenya. *Applied Geography, 117*, 102185.

Sillero-Zubiri, C., & Switzer, D. (2001). Crop raiding primates: searching for alternative, humane ways to resolve conflict with farmers in Africa. Wildlife Conservation Research Unit. Oxford: Oxford University, pp. 1-19.

Singer, J. B. (2010). Norms and the network: Journalistic ethics in a shared media space. In: Meyers, C. (Ed.), *Journalism Ethics: A philosophical approach*. Oxford: Oxford University, pp. 117-129.

Thatcher, H. R., Downs, C. T., & Koyama, N. F. (2019a). Anthropogenic influences on the time budgets of urban vervet monkeys. *Landscape and Urban Planning, 181*, 38-44.

Thatcher, H. R., Downs, C. T., & Koyama, N. F. (2019b). Positive and negative interactions with humans concurrently affect vervet monkey (*Chlorocebus pygerythrus*) ranging behavior. *International Journal of Primatology, 40*(4), 496-510.

Thatcher, H. R., Downs, C. T., & Koyama, N. F. (2020). Understanding foraging flexibility in urban vervet monkeys, *Chlorocebus pygerythrus*, for the benefit of human-wildlife coexistence. *Urban Ecosystems, 23*, 1349-1357.

van Houdt, S., Brown, R. P., & Traill, L. W. (2021). Stakeholder attitudes toward the incentives used to mitigate human-elephant conflict in southern Africa: A news media content analysis. *Journal for Nature Conservation, 61*, 1-8. doi:https://doi.org/10.1016/j.jnc.2021.125982

Wimberger, K. (2008). Wildlife rehabilitation in South Africa. PhD thesis, University of KwaZulu-Natal, Pietermaritzburg.

Wimberger, K., & Downs, C. T., (2010). Annual intake trends of a large urban animal rehabilitation centre in South Africa: a case study. *Animal Welfare, 19*, 501. https://www.academia.edu/21250803/.

Wimberger, K., Downs, C. T., & Perrin, M. R. (2010). Post-release success of two rehabilitated vervet monkey (*Chlorocebus aethiops*) troops in KwaZulu-Natal, South Africa. *Folia Primatologica, 81*, 96-108. https://doi.org/10.1159/000314636

Young, C., McFarland, R., Ganswindt, A., Young, M. M. I., Barrett, L., & Henzi, S. P. (2019). Male residency and dispersal triggers in a seasonal breeder with influential females. *Animal Behaviour, 154*, 29-37.

Zungu, M. M., Maseko, M. S. T., Kalle, R., Ramesh, T., & Downs, C. T. (2020). Factors affecting the occupancy of forest mammals in an urban-forest mosaic in EThekwini Municipality, Durban, South Africa. *Urban Forestry & Urban Greening, 48*, e00878. doi:10.1016/j.ufug.2019.126562

CHAPTER 6

Conclusions and recommendations

6.1 Background

The human population continues to expand, of which 55% of the world's population lives in urban areas, and this is expected to grow to 2.5 billion people by 2050 only in urban areas, with close to 90% of this growth taking place in Africa (UN, 2018). Urbanisation is a contributing factor to anthropogenic land-use change that threatens biodiversity worldwide (Grimm et al., 2008). Urbanisation generally negatively impacts biodiversity assemblages (Concepción et al., 2015). Urban sprawl, human expansion, and migration into urban areas, coupled with land transformation for infrastructure development, recreation, industrialisation, and agriculture, are some anthropogenic activities that further exacerbate the situation for wildlife existing in urban environments (Simon, 2008; O'Connor & Kuyler, 2009). Generally, human-induced environmental changes act as a non-random filter allowing only the most adaptable species to survive under modified conditions, known as biotic homogenisation (Smart et al., 2006). However, other studies show that some of these altered landscapes generally have a mix of anthropogenic and natural elements creating mosaic urban landscapes that offer opportunities for the persistence of certain species (McCleery et al., 2012; Fournier et al., 2020; Spotswood et al., 2021; Downs et al., 2021). Certain species, often generalists, adapt well to transformed landscapes. Therefore, it is important to understand how wildlife populations and communities respond to these impacts to deal with potential human-wildlife conflicts.

With increasing urbanisation, it is necessary to know what drives species to be successful, particularly in intensively modified landscape mosaics. It is important to determine what factors promote species to fourish and limit their survival. Primate responses to urbanisation are variable and often species-specific (Hoffman & O'Riain, 2012a,b; McKinney,

2015; McLennan et al., 2017). Certain primate populations have adapted ecologically, physiologically, or behaviorally well (Hoffman & O'Riain, 2012a,b; Thatcher et al., 2020). In urban settings, many of these primate species appear to flourish depending on the availability of resources, as well as the quality and quantity of resources available in the existing environment. The vervet monkey (*Chlorocebus pygerythrus*) is one such species that flourish in urban mosaic landscapes (Nowak & Lee, 2013; Patterson et al., 2018; Thatcher et al., 2020). The area that supports troops of vervet monkeys has greater resources like food and living space that promote its abundance. Despite high levels of urbanisation observed in eThekwini Municipality, KwaZulu-Natal, South Africa, one of the features that stand out in this city is the daily reported number of vervet monkeys sighted in and around the suburbs, town, and urban periphery (Patterson et al., 2017; pers. obs.). Additionally, the increased reports by the public of human-vervet monkey interactions are also predominant in the province. Therefore, this study has enhanced our understanding of the need to determine the behavioural ecology, persistence and human-wildlife conflict experienced by this primate in mosaic urban landscapes.

6.2 Summary of findings

The first objective was to document home range size, core areas and habitat use of vervet monkeys occurring in very different habitat types, using global positioning systems (GPS) telemetry data from tracking six individual vervet monkeys in the urban forest mosaic landscape of the eThekwini Municipality (Chapter 2). This study added to findings from previous studies in the region. GPS tracking data indicated that the overall mean home range and core area size was relatively small for vervet monkeys but similar to previous studies and showed individual variations (Patterson et al., 2019). Urban-residential vervet monkeys travelled less than their forest counterparts (Chapter 2). Habitat use of vervet monkeys in the

greener areas utilised forest and thicket, and built-up habitat types more frequently, and the urban-residential troop utilised built-up areas in proportion to available; and the forest, thicket and grassland were used less than what was available (Chapter 2). These results further support that vervet monkeys are generalist species and exhibit behavioural flexibility in terms of home range and habitat use in the urban mosaic landscape.

The second objective was to determine human-wildlife conflicts experienced between vervet monkeys and people by using admission data from a wildlife rehabilitation centre in the eThekwini Municipality from 2011-2018 in the eThekwini Municipality (Chapter 3). Historical data obtained from rehabilitation centres can provide researchers with valuable information for long-term retrospective studies on wildlife (Wimberger & Downs, 2010; Taylor-Brown et al., 2019). The data from an urban wildlife rehabilitation centre showed significant annual increases in intake and seasonal trends, with most vervet monkeys admitted in spring. Overall, more juvenile males were admitted than females. The highest causes of admission for vervet monkeys were being hit by motor vehicles, unknown causes, dog attacks and orphans. Most of the vervet monkeys arrived alive at the centre; however, 71% were declared dead by the end of the admission process (Chapter 3). We additionally determined the odds of survivability of an admitted vervet monkey which varied by seasons, age class, location of the eThekwini Municipality and cause of admission. The highest predictor for survivability was for the cause of admission as pets, with the likelihood to survive being 21.5 times greater than motor vehicle strikes (Chapter 3). Vervet monkeys in the eThekwini Municipality are most vulnerable to anthropogenic threats leading to their demise.

A unique relationship exists between vervet monkeys and people. Although conflict exists, urban wildlife rehabilitation centres provide a place where wildlife can be rescued, rehabilitated and released. These centres also provide novel data on events that take place in urban wildlife species. Therefore, in Chapter 4, we describe the first observations of pregnancy

cases exhibiting dystocia of recorded admission cases of vervet monkeys at an urban rehabilitation facility in the eThekwini Municipality between 2012 and 2018. There is little literature on dystocia in wild vervet monkeys. The objective was to determine the cause of pregnancy complications documented in wild female vervet monkeys using admission data. We documented pregnancy complications of dystocia, birthing complications, and retained placenta in pregnant females. We also reported on detailed medical information concerning the cause of admission, treatment, and outcome for each case. Vervet monkeys that displayed signs of birthing complications had no successful births despite medical treatment, and most (84.6%) succumbed to their injuries (Chapter 4). We suggest that variable climatic and weather phenomena are impacting natural food availability, and the feeding of artificial sources of food could be causing complications in vervet monkey births in urban areas of Durban.

Lastly, media content analysis of 332 vervet monkey-related online newspaper articles published in forty-five South African online news sources from 1999 to 2020 was quantified (Chapter 5). This study aimed to assess and quantify the media's response to reporting on vervet monkeys in South Africa. Using content analysis to understand how media influences public perceptions effectively identified the main themes and frames of the "vervet-monkey problem" in South Africa (Krippendorff, 2018). We found a significant increase in the number of online articles published over the years with no seasonal differences. Long-term coverage on the nature of events was mostly negative and documented directly affecting vervet monkeys. There was an increase in human-vervet interactions, often leading to shooting, animal abuse and poisoning incidences (Chapter 5). Human-wildlife conflict occurs at the interface when interactions between humans and wildlife turn negative, leading to the use of harmful and lethal tactics on wildlife to reduce conflict (Distefano, 2005; Schell et al., 2021). The frequency and severity of interactions differed amongst people's perceptions and habits (Soulsbury & White, 2019), often leading to debating the "pro-or-anti" vervet monkey campaign. Nonetheless,

vervet monkeys were harshly persecuted in South Africa, especially in KwaZulu-Natal Province. Overall, we found that wildlife and primate rehabilitation centres and the NSPCA were the main organisations in alleviating the human-vervet conflict situation through rescues, education, and preventive measures. We also found that these centres were important for providing means of medical assistance to injured vervet monkeys and educating the public about living with wildlife (Chapter 5).

The results presented in this study highlighted the plight of urban vervet monkeys and support the need for education, management, and conservation of this conflict primate species in the urban mosaic landscapes of South Africa.

6.3 Future research

This thesis explains the persistence and utilisation of the urban mosaic landscape by a single primate species, vervet monkeys, in eThekwini Municipality, KwaZulu-Natal. The results presented here have shown that landscapes characterised by urban-forest mosaics support vervet monkey troops in these human-dominated landscapes. Furthermore, vervet monkeys utilise anthropogenic environments but are negatively persecuted because of human-wildlife conflict. Many vervet monkeys are subjected to injuries or mortality because of direct or indirect acts of humans.

Several questions have been answered with the results of this study; however, the fact that all behavioural and aspects of the ecology of vervet monkeys were not addressed, the following future studies are proposed:

i. Despite our efforts to capture and fit transmitters, in the present research, we only managed to successfully track six individual vervet monkeys for less than a year. Although four males were tagged, only two GPS collars were effective in this study. A long-term study with larger sample sizes, with an equal number of males and females,

from several different troops, at various locations is required for further understanding of how home range and core areas vary between the sexes and seasonal comparisons.

ii. We did not quantify the population estimates of all existing populations of vervet monkeys in the eThekwini Municipality, but rather obtained troop estimates only for specific areas in this study. It is hoped that further research into quantifying vervet monkey populations through physical counts could determine the overall effect of human-wildlife conflict on the existing population.

iii. We did not compare non-urban female vervet monkeys with pregnancy complications or record the number of sexually active females with offspring. This study will generate a baseline of the expected pregnancy rate and determine what proportion of the breeding females suffer pregnancy complications by using admission rates against the annual recruitment into the population. The proportion of complications can be estimated using pregnancy complications to determine if it is related to anthropogenic factors.

iv. The impact of direct feeding and human waste management is required to determine the effects of artificial food sources on vervet monkeys' metabolic, physiological, and behavioural characteristics.

v. The long-term impacts of rehabilitation and release or long-term captivity and release are needed to understand the success of outcomes provided by wildlife rehabilitation centres.

6.4 Conservation recommendations

Although vervet monkeys are ranked as a Least Concern species (Butynski & De Jong, 2019), this primate does not deserve any less conservation protection efforts. We recommend a proactive stance on the conservation and welfare of the species rather than delaying mitigation measures, without which could lead to their extirpation in urban areas. As observed in this

study, habitat encroachment has allowed for higher rates of human-vervet interactions in mosaic urban forest landscapes across South Africa. With increasing urban sprawl, the reality of people encountering vervet monkeys is common, especially in the eThekwini Municipality. Vervet monkeys are opportunistic species showing ecological and behavioural flexibility to human-modified landscapes (Patterson et al., 2027, 2018, 2019; Nowak & Lee, 2013; Thatcher et al., 2020). South Africa cannot completely eradicate human-vervet conflict. This is nearly impossible, but when adaptive thinking is applied to well-planned and integrated management practices, we can potentially reduce conflicts whilst promoting the coexistence between people and vervet monkeys. These approaches need to work on response, mitigation, prevention, research, and monitoring, all backed by strong supporting policies and public participation (Hockings & Humle, 2009). Below, we provide the following recommendations to support the protection of vervet monkeys.

The media plays an important role in guiding public opinions and attitudes towards vervet monkeys and other wildlife. From this study, online newspaper articles have been reporting negative stories of vervet monkeys. We recommend that journalists report on optimistic stories of urban vervet monkeys and provide further information on how to co-exist with the species. Additionally, providing educational material and writing about animal welfare laws and legislation could curb the poisonings and shootings of vervet monkeys as more people will be informed about the legalities of wildlife.

Research under an academic context, similar to this study, is important in providing key evidence to support mitigation efforts for environmental legislation and policies for all wildlife. Conservation legislation protects all wildlife, including vervet monkeys. This should be firmly applied and enforced by national authorities despite the differences in provincial legislation. The present study revealed human causes that directly harm vervet monkeys: motor vehicle strikes, dog attacks and animal cruelty. Harsher sentences on perpetrators abusing or inflicting

any form of harm to any wildlife are strongly needed. Additionally, we recommend that wildlife, primate and vervet rehabilitation centres or sanctuaries practice the fundamental aspect of rehabilitating and release (Wimberger, 2008; Wimberger et al., 2010; Guy et al., 2013; Pyke & Szabo, 2018). The keeping of severely injured vervet monkeys that cannot be released back into the wild is inhumane, and the responsibility falls on the rehabilitator for providing its daily needs. Rehabilitators should not create an oasis or a false haven for vervet monkeys in the hope that donations will fulfil their expenses. Furthermore, not releasing animals back into the wild becomes a hoarding practice to rehabilitators that can lead to a breach of permit conditions as the breeding of vervet monkeys takes place, increasing the populations housed in captivity. Contact between humans and primates should be limited and even reduced contact between the hand-rearing of orphan primates. If an animal becomes imprinted and tame, it becomes difficult to release into the wild (Wimberger, 2008; Navarro & Martella, 2011). Wild animals are instinctive, but rehabilitators can alter the animal's psychological and natural behaviour through long-term rehabilitation without release (Navarro & Martella, 2011). We also provide the following methods and recommendations to avoid further human-vervet conflict (Table 6.1; Fig. 6.1).

Fig. 6.1 A sign posted at a picnic area in a South African game reserve to urge the public not to feed vervet monkeys.

Table 6.1 Methods and recommendations for vervet monkeys in South Africa to reduce human-vervet monkey wildlife conflict.

Method	Recommendations
Education	Educating the public on vervet monkey behaviour and habits is supported and should start at the grassroots level. Farmers, property owners, tourist attractions and the greater public also need to be educated on limiting their interactions and close contact (Humle & Hill, 2016).
Waste management	Better waste management by all to stop foraging in homes and gardens could be done through monkey-proof bins and locking away food items (Sekarningrum, 2016; Thatcher et al., 2020).
Feeding of wildlife	The ban on feeding all vervet monkeys is supported. This will also prevent poisoning events and behavioural changes, including the loss of fear of humans by displaying risky behaviour for food acquisition (Dittus et al., 2019; Thatcher et al., 2020).
Signage	Adequate signage placed at high human-vervet conflict areas to notify the public of how to react and behave around vervet monkeys (Bonnell & Breck, 2017).
Coexistence	As vervets have adapted to human-modified landscapes, people also need to be tolerant and accepting of their presence (Dittus et al., 2019).

6.4.1 Vervet monkey welfare

In South Africa, animal welfare is governed by the Animal Protection Act No. 71 of 1962, which prohibits animal cruelty on all domestic and wild animals in captivity or under the control of humans; and the Performing Animals Protection Act No. 24 of 1935 (amended in 2016), which requires establishments training animals for exhibitions or performance, or training guard dogs, to be licensed. Both these acts are under the jurisdiction of the Department of Agriculture, Rural Development and Land Reform (DARDLR). While "welfare" cannot solely be defined by legislative provisions, it is important to note that national issues and problems relating to animals and wildlife are being addressed through regulations, codes of Practice and by-laws. This includes the transportation of wild and farm animals, protocols relating to the sale and export of animals and the capture of wild animals. It is highlighted that wild animal regulation in South Africa "follows the traditional but outdated distinction between

animal welfare and biodiversity conservation". Wild animal welfare is not a priority right now and the focus of legislation is put on conserving the species as a whole. On the other hand, the National Council of SPCAs (NSPCA), have enacted a series of animal welfare standards but only in relation to certain species of animals which are mostly domestic animals. The legislation exists, but the jurisdiction is blurred among the state and who is responsible for enforcing the legislation on the welfare of wildlife and whether wildlife have welfare rights. This is questionable for all wildlife in South Africa, as people continue to hurt and maim vervet monkeys, as documented in this study.

6.4.2 Primate Task Team

During this study, several workshops were held with various stakeholders addressing the vervet conflict problem in eThekwini Municipality. These workshops included individuals from their field of interest: biologists, conservationists, social scientists, veterinarians, wildlife rehabilitators and practitioners, ward councillors, researchers, and academics, who would cooperatively address human-wildlife conflict caused by vervets. Although no end solution was identified, these workshops identified that an issue does exist amongst people and vervets, and more intervention programmes are needed to assist the public in dealing with vervets. Workshop participants also identified gaps and needs in human-wildlife conflict prevention and mitigation, including those related to capacity, tools, research, management, policies, and legislation. Finally, the suggestion of a Primate Task Team for all indigenous primates from South Africa was supported by all attendees of the workshop for better coordination and implementation of recommendations. A list of approaches is highlighted in Table 6.1 that can be achievable through an evaluation of all stakeholders developed by the Primate Task Team which is likely to turn the broad focus areas into achievable action items. Pragmatic methods and solutions must be considered when finding a balance between humans and primates in a

shared habitat. As urbanisation increases, human-modified landscapes increase, and the natural spaces for vervets will become limited in eThekwini Municipality without management. Studies like these will contribute findings for practical management solutions for the conservation of species impacted by human-wildlife conflict and educate people that coexistence is important and possible.

6.5 Concluding remarks

Over the last two decades, the survival of vervet monkeys has been compromised mainly because of anthropogenic activities in the urban mosaic landscapes of South Africa. The increased frequency of interactions between people and vervet monkeys has triggered conflict leading to persecution of the species. However, these vervet monkeys have shown unique and adaptable ecological capabilities near human-dominated areas. From this study, urban vervet monkeys face a serious welfare crisis, not just a conservation problem. There might be conservation issues later because of localised extinction, but the species presently do not face a conservation crisis. Human intervention and medical assistance from wildlife rehabilitation centres can also assist wounded urban vervet monkeys, depending on the scale of injury. This study has established that anthropogenic, pre-emptive, and inhumane acts on an individual and/or vervet monkey troops exist, often leading to harsh deaths. Without vigorous actions and intervention, this could ultimately lead to the long-term extinction of the species in areas where they once occurred naturally.

6.5 References

Bonnell, M. A., & Breck, S. W. (2017). Using resident-based hazing programs to reduce human-coyote conflicts in urban environments. *Human-Wildlife Interactions*, *11*(2), 5.

Butynski, T. M., & De Jong, Y. A. (2019). *Chlorocebus pygerythrus* [Technical Report]. *The IUCN Red List of Threatened Species*, 1-9. https://doi.org/DOI:10.2305/IUCN.UK.2008.RLTS.T136271A4267738.en

Concepción, E. D., Moretti, M., Altermatt, F., Nobis, M. P., & Obrist, M. K. (2015). Impacts of urbanisation on biodiversity: the role of species mobility, degree of specialisation and spatial scale. *Oikos*, *124*(12), 1571-1582. https://doi.org/10.1111/oik.02166

Distefano, E. (2005). Human-wildlife conflict worldwide: collection of case studies, analysis of management strategies and good practices. *Food and Agricultural Organization of the United Nations* 1-34. https://doi.org/http://www.fao.org/documents

Dittus, W. P. J., Gunathilake, S., & Felder, M. (2019). Assessing public perceptions and solutions to human-monkey conflict from 50 years in Sri Lanka. *Folia Primatologica*, *90*(2), 89-108.

Downs, C.T., Alexander, J., Brown, M., Chibesa, M., Ehlers Smith, Y.C., Gumede, S.T., Hart, L.A., Kalle, R., Maphalala, M., Maseko, M., McPherson, S., Ngcobo, S.P., Patterson, L., Pillay, K., Price, C., Raji, I.A., Ramesh, T., Schmidt, W., Senoge, N.D., Shivambu, T.C., Shivambu, N., Singh, N., Singh, P., Streicher, J., Thabethe, V., Thatcher, H., Widdows, C., Wilson, A.L., Zungu, M.M., & Ehlers Smith, D. (2021). Modification of the third phase in the framework for vertebrate species persistence in connected urban environments based on a review of case studies from KwaZulu-Natal Province, South Africa. *Ambio, 50,* 1866–1878. https://doi.org/10.1007/s13280-021-01501-5

Fournier, B., Frey, D., & Moretti, M. (2020) The origin of urban communities: From the regional species pool to community assemblages in the city. *Journal of Biogeography, 47*, 615–629. https://doi.org/10.1111/jbi.13772

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global Change and the Ecology of Cities. *Science*, *319*(5864), 756-760. https://doi.org/doi:10.1126/science.1150195

Guy, A. J., Curnoe, D., & Banks, P. B. (2013). A survey of current mammal rehabilitation and release practices. *Biodiversity and Conservation*, *22*(4), 825-837.

Hockings, K., & Humle, T. (2009). *Best practice guidelines for the prevention and mitigation of conflict between humans and great apes*. IUCN/SSC Primate Specialist Group. www.primate-sg.org/

Hoffman, T. S., & O'Riain, M. J. (2012a). Landscape requirements of a primate population in a human-dominated environment. *Frontiers in Zoology, 9*(1), 1-17.

Hoffman, T. S., & O'Riain, M. J. (2012b). Monkey management: using spatial ecology to understand the extent and severity of human-baboon conflict in the Cape Peninsula, South Africa. *Ecology and Society, 17*(3), 1-16.

Humle, T., & Hill, C. (2016). People-primate interactions: implications for primate conservation. In: Wich, S. A. & Marshall, A. J. (Eds.), *An Introduction to Primate Conservation*. Oxford: Oxford University Press, pp. 219-240.

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. Sage publications.

McCleery, R., Moorman, C., Wallace, M., & Drake, D. (2012) Managing Urban Environments for Wildlife. In: Silvy, N. J. (ed) The Wildlife Techniques Manual: Management. John Hopkins University Press, Baltimore, pp 169–191

McKinney, T. (2015) A classification system for describing anthropogenic influence on nonhuman primate populations. *American Journal of Primatology, 77,* 715–726. https://doi.org/10.1002/AJP.22395

Navarro, J., & Martella, M. (2011). Ratite conservation: Linking captive-release and welfare. In: Glatz, P., Lunam, C. & Malecki, I. (Eds). *The Welfare of Farmed Ratites*. Springer, pp. 237-258.

Nowak, K., & Lee, P. C. (2013). “Specialist” primates can be flexible in response to habitat alteration. In: Marsh, L. K. (Ed.), *Primates in Fragments*: *Ecology and Conservation*. Springer, pp. 199-211.
O'Connor, T. G., & Kuyler, P. (2009). Impact of land use on the biodiversity integrity of the moist sub-biome of the grassland biome, South Africa. *Journal of environmental management*, *90*(1), 384-395.
Patterson, L., Kalle, R., Downs, C. T. (2017). A citizen science survey: Perceptions and attitudes of urban residents towards vervet monkeys. *Urban Ecosystems, 20,* 617-628. https://doi.org/10.1007/s11252-016-0619-0
Patterson, L., Kalle, R., & Downs, C. T. (2018). Factors affecting presence of vervet monkey troops in a suburban matrix in KwaZulu-Natal, South Africa. *Landscape and Urban Planning, 169,* 220-228. https://doi.org/10.1016/j.landurbplan.2017.09.016
Patterson, L., Kalle, R., & Downs, C. T. (2019). Living in the suburbs: Space use by vervet monkeys (*Chlorocebus pygerythrus*) in an eco-estate, South Africa. *African Journal of Ecology*, *57*(4), 539-551.
Pyke, G. H., & Szabo, J. K. (2018). Conservation and the 4 Rs, which are rescue, rehabilitation, release, and research. *Conservation Biology*, *32*(1), 50-59.
Schell, C. J., Stanton, L. A., Young, J. K., Angeloni, L. M., Lambert, J. E., Breck, S. W., & Murray, M. H. (2021). The evolutionary consequences of human-wildlife conflict in cities. *Evolutionary Applications*, *14*(1), 178-197.
Sekarningrum, A. (2016). The Analysis of Ecotourism Principle on Methods of Waste Disposal to Minimize Negative Impacts in Baluran National Park. *Gadjah Mada Journal of Tourism Studies*, *3*(2), 86-96.
Simon, D. (2008). Urban environments: issues on the peri-urban fringe. *Annual Review of Environment and Resources*, *33*, 167-185.
Smart, S. M., Thompson, K., Marrs, R. H., Le Duc, M. G., Maskell, L. C., & Firbank, L. G. (2006). Biotic homogenization and changes in species diversity across human-modified ecosystems. *Proceedings of the Royal Society B: Biological Sciences*, *273*(1601), 2659-2665. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1635461/pdf/rspb20063630.pdf
Spotswood, E. N., Beller, E. E., Grossinger, R., Grenier, J. L., & Heller, N. E. (2021). The biological deserts fallacy: Cities in their landscapes contribute more than we think to regional biodiversity. *BioScience, 71,* 148-160. https://doi.org/10.1093/biosci/biaa155
Soulsbury, C. D., & White, P. C. L. (2019). A framework for assessing and quantifying human-wildlife interactions in urban areas. In: Frank, B., Glikman, J., & Marchini, S. (Eds.), *Human–Wildlife Interactions: Turning Conflict into Coexistence (Conservation Biology).* Cambridge: Cambridge University Press. pp. 107-128. doi:10.1017/9781108235730.009
Taylor-Brown, A., Booth, R., Gillett, A., Mealy, E., Ogbourne, S. M., Polkinghorne, A., & Conroy, G. C. (2019). The impact of human activities on Australian wildlife. *PLoS One*, *14*(1), e0206958. https://doi.org/10.1371/journal.pone.0206958
Thatcher, H. R., Downs, C. T., & Koyama, N. F. (2020). Understanding foraging flexibility in urban vervet monkeys, *Chlorocebus pygerythrus*, for the benefit of human-wildlife coexistence. *Urban Ecosystems*, *23*, 1349-1357.
UN. (2018). *World Urbanization Prospects 2018*. https://population.un.org/wup/
Wimberger, K. (2008). Wildlife rehabilitation in South Africa. PhD thesis, University of KwaZulu-Natal, Pietermaritzburg.
Wimberger, K., & Downs, C. T. (2010). Annual intake trends of a large urban animal rehabilitation centre in South Africa: a case study. *Animal Welfare*, *19*(4), 501-513.

Wimberger, K., Downs, C. T., & Perrin, M. R. (2010). Post-release success of two rehabilitated vervet monkey (*Chlorocebus aethiops*) troops in KwaZulu-Natal, South Africa. *Folia Primatologica, 81*, 96-108. https://doi.org/10.1159/000314636