Urban Ecology of the Vervet Monkey *Chlorocebus pygerythrus* in KwaZulu-Natal, South Africa

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ABSTRACT

The spread of development globally is extensively modifying habitats and often results in competition for space and resources between humans and wildlife. For the last few decades a central goal of urban ecology research has been to deepen our understanding of how wildlife communities respond to urbanisation. In the KwaZulu-Natal Province of South Africa, urban and rural transformation has reduced and fragmented natural foraging grounds for vervet monkeys *Chlorocebus pygerythrus*. However, no data on vervet urban landscape use exist. They are regarded as successful urban exploiters, yet little data have been obtained prior to support this. This research investigated aspects of the urban ecology of vervet monkeys in three municipalities of KwaZulu-Natal (KZN), as well as factors that may predict human-monkey conflict.

Firstly, through conducting an urban wildlife survey, we were able to assess residents' attitudes towards, observations of and conflict with vervet monkeys, investigating the potential drivers of intragroup variation in spatial ecology, and identifying predators of birds' nests. We analysed 602 surveys submitted online and, using ordinal regression models, we ascertained that respondents' attitudes towards vervets were most influenced by whether or not they had had aggressive interactions with them, by the belief that vervet monkeys pose a health risk and by the presence of bird nests, refuse bins and house raiding on their properties.

Secondly, to investigate the vervet monkeys perceived negative impact on urban nesting birds, 75 artificial nests were deployed, and monitored by camera traps. Overall, 17 were depredated, 15 by monkeys and two by domestic cats *Felis catus*. It was determined that future experiments on natural nest predation are essential for comparison.

Thirdly, by collecting observational data on 20 vervet monkey troops living in a variety of developed landscapes within KZN, it was found that the key landscape features influencing vervet monkey troop-level visitation rates, durations and observed foraging in residences were the absence of dogs, presence of supplementary food provisioning, fruiting trees, trees taller than two meters, and a high percentage of tree coverage. Data analysis revealed higher visitation rates during winter, in gardens with higher tree density, and the highest foraging rates in gardens closer to main roads, where supplementary provisioning and bird feeders were present. Furthermore, gardens with greater canopy cover had higher rates of feeding, grooming and playing, which all decreased with increasing troop size, while resting rates decreased with increasing distance from indigenous forest patches and main roads. Gardens experiencing comparatively low levels of visitation experienced high levels of raiding. The combination of these variables appears to provide monkeys with predictable, accessible, indigenous, exotic and anthropogenic food sources in human-modified habitats within close proximity to suitable sleeping sites and safety.

Lastly, we examined vervet monkey space use using GPS/UHF telemetry data from 10 vervet monkeys across six troops over nine months within a 420 ha eco-estate. We documented a mean home range of 0.99 km^2 (95% MCP) and 1.07 km^2 (95% FK) for females (n = 6), 1 km^2 (95% MCP) and 1.50 km^2 (95% FK) for males (n = 4) and 0.87 km^2 (95% MCP) and 1.12 km^2 (95% FK) for troops (n=6), respectively, indicating that males and larger troops had larger home ranges. These relatively small home ranges included shared territorial boundaries and high home range overlap. Vervet monkey movements indicated higher morning activity levels and habitat selection indicated significantly more use of golf course, urban residential and forest, thicket and woodland areas, and avoidance of wetland, grassland and shrub, and urban built-up areas. Our results suggest that modified-habitat use by vervet monkeys is a consequence of behavioural facilitation to access highly-available food resources, thereby facilitating their persistence in developing ecosystems in South Africa. Therefore, conflict management is dependent on the conservation of sufficient natural habitats and food resources, to minimize their dependence on manmade resources and consequently reduce human-monkey conflict.

The results contributed to an understanding of the drivers of urban vervet monkey spatial ecology within a transformed landscape. This hopefully will assist in determining the most sustainable way to mitigate conflict and manage vervet monkeys in these municipalities. In a broader context, this study highlights the value of citizen science and wildlife spatial ecology studies in providing mechanisms for identifying priority management and conservation efforts at the highly complex human-wildlife interface.

PREFACE

The data described in this thesis were collected in the Ethekwini and Msunduzi Municipalities, Republic of South Africa from March 2013 to March 2017. Experimental work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg campus, under the supervision of Professor Colleen T. Downs and Dr Riddhika Kalle.

This thesis, submitted for the degree of Doctorate of Philosophy in the College of Agriculture, Engineering, and Science, University of KwaZulu-Natal, 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.

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

Downs

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Professor Colleen T. Downs
Supervisor
August 2017

COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE DECLARATION 1 – PLAGIARISM

I, Lindsay Leigh Patterson, 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.

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

Publication 1
Patterson L, Kalle R, Downs C. (2017) A citizen science urban wildlife survey: perceptions and attitudes of urban residents towards vervet monkeys. *Urban Ecosystems* 20: 617-628. DOI 10.1007/s11252-016-0619-0
Minor edits made since publication.

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

Publication 2
Patterson L, Kalle R, Downs C. (2016) Predation of artificial bird nests in suburban gardens of KwaZulu-Natal, South Africa. *Urban Ecosystems* 19: 615-630. DOI 10.1007/s11252-016-0526-4
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LP conceived paper with CTD. LP collected data. LP analysed data with RK. LP wrote the paper. CTD, RK and reviewers contributed valuable comments to the manuscript.

Publication 3
Patterson L, Kalle R, Downs C. (2017) Factors affecting presence of vervet monkey troops in a suburban matrix in KwaZulu-Natal, South Africa. *Landscape & Urban Planning.* 169: 220-228. https://doi.org/10.1016/j.landurbplan.2017.09.016
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LP conceived paper with CTD. LP collected data. LP analysed data with RK. LP wrote the paper. CTD, RK and reviewers contributed valuable comments to the manuscript.

Publication 4
Patterson L, Kalle R, Downs C. In prep. Living in the suburbs: Space use by vervet monkeys (*Chlorocebus pygerythrus*) in Simbithi Eco-Estate, South Africa. Formatted for *American Journal of Primatology*.

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

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I dedicate this thesis to my husband, whose patience and support have made me and my research stronger, and to the monkeys that inspire me.

Photo credit: Arne Leisegang 2016

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CHAPTER 1
INTRODUCTION

1.1 Urban ecology

1.1.1 Background

The global growth of urban enviornments is one of the most prominent impactors on wildlife and it's interactions with humans (United Nations Population Fund, 2007). Over the last three centuries the human population has grown and expanded its occupation of the planet at an unprecedented rate, leading to the global restructuring of wild to human-modified landscapes (McKinney 2006; Ellis et al. 2010). Urban-dwelling human populations are now the majority, with a projected global growth to five billion by 2030 (United Nations, 2006). This population growth leads to further land-use demands for urban growth, which may lead to an expected 1.2 million km2 of land transformation within the next three decades (Seto *et al.*, 2012). It is with this in mind, that the discipline of urban ecology has become increasingly important and relevant, endeavoring to integrate wildlife and human populations at high density, urban interfaces into mutually supportive ecosystems (McKinney 2002, Alberti et al. 2003, Marzluff et al. 2008).

The process of converting rural and natural areas into urban environments, known as urbanisation, involves some of the most extreme and rapid forms of irreversible land use alteration (Collins et al. 2000), and in many cases constricts species into marginal and fragmented habitat patches in direct competition with local human communities (Siex and Struhsaker 1999a; Distefano 2005). Animal diversity and abundance may be altered radically in urban ecosystems relative to wildlands, due to habitat homogenisation and low food diversity as a consequence of humans' converting, compressing and fragmenting natural lands for their own purposes (Western 2001; Gaston 2005). While it has been shown that a relatively high availability of food and roost sites in some cities may support high animal densities (Marzluff 2001), increasingly, urbanisation has been shown to lead to local wildlife diversity declines (McIntyre 2000) and increased human-wildlife conflict (HWC) (Siex and Struhsaker 1999a; Woodroffe et al. 2005).

Indigenous wildlife is negatively impacted by land transformation and fragmentation of natural habitats, and the diversity of indigenous species decreases in proximity to the core of urban development (Kark et al. 2007; Reis et al. 2012). In the most extreme cases, urbanisation has led to the complete restructuring of the fauna and flora composition of environments (McKinney 2006). It is therefore considered to be the leading probable cause of extinction across wildlife species (Pimm and Raven 2000). Urbanisation and its effects on wildlife are therefore of great concern in conservation biology (McKinney 2006). Decreases in urban wildlife diversity are often a result of competition (Shochat 2004; Shochat et al. 2006). Efficient colonisers can thrive in cities within regions where they may normally not, and an increasing abundance of species that are highly efficient food exploiters can cause decreases in native species (Shochat 2004; Shochat et al. 2006).

1.1.2 The urban human-wildlife interface

Interactions with wildlife occur most regularly around protected wildlife areas, where wildlife populations tend to be most concentrated and animals stray within close proximity to adjacent private land and human habitations. It is here where resources are easiest to obtain and opportunistic species are most likely to be perceived as pests (Estrada and Butler 2012). These patterns exist in many regions of the world where urbanisation has brought humans into closer contact with wildlife species. However, despite these challenges, some species are able to adapt and persist in the face of human-induced transformation (McKinney 2002; DeStefano and DeGraaf 2003; Smith and Gehrt 2010; Hoffman and O'Riain 2012; Albert et al. 2014). Some urban adapters may tolerate changes, while still requiring areas of natural habitats to persist, while urban exploiters can effectively use and benefit from the availability of anthropogenic resources to thrive in urban environments (Parker & Nilon 2012). Some exploiter species make such effective use of anthropogenic resources and opportunities that, despite reduced species richness, the overall urban biomass can be higher than surrounding natural habitats (McKinney 2006; Kark et al. 2007).

Non-human primates (hereafter referred to as 'primates') present conservation biologists with some of the most complex conservation and management challenges at the human-wildlife interface, on a global scale (Sponsel et al. 2002). The majority of primate species worldwide are severely threatened by habitat loss and anthropogenic modification (Priston and McLennan 2013). However, the responses of individual taxa to increasingly urbanised environments occur along a tolerance gradient ranging from local extinction (intolerance) to apparent benefit (ecological and behavioural adaptation see Table 1.1 for examples) (Gautier and Biquand 1994; Priston and McLennan 2013).

1.1.3 Urban adapted non-human primates

Humans and primates' evolutionary convergence of ecological requirements, widespread across Africa, Asia, South and Central America and Madagascar, is most likely responsible for their geographical overlap (sympatry) across the tropics (Sponsel et al. 2002). Unfortunately, human-induced habitat disturbance is documented as the primary cause for the 'endangered' classification of 92% of all primate species (IUCN 2010). Most prominent is the loss of habitat through deforestation; agricultural development, and encroachment on natural habitats, often within narrow ecological niches, and the resultant lack of habitat and food that specialist primates rely on for their survival (Emmons et al. 1983; Jernval and Wright 1998). However, generalist primates with flexibility in diet and behavior tend to be less

Table 1.1. Examples of non-domesticated, urban-adapted wildlife worldwide, listed as Least Concern on the IUCN Red List of Threatened Species.

Species	**Country**	**Reference**
Burrowing owl *Athene cunicularia*	United States	Rebolo-Ifrán et al. 2017
Cane toads *Rhinella marina* (non-native)	Australia	Urban et al., 2008
Chacma baboons *Papio ursinus*	South Africa	Hoffman & O'Riain, 2012
Common Myna *Acridotheres tristis* (non-native)	Australia	Lowe et al., 2011
European badger *Meles meles*	England	Huck et al. 2008
Hadeda ibis *Bostrychia hagedash*	South Africa	Singh & Downs, 2016
Kuhl's pipistrelle bat *Pipistrellus kuhlii*	Italy	Ancillotto et al. 2015
Large spotted genets *Genetta tigrina*	South Africa	Widdows & Downs 2018
Long-tailed macaque *Macaca fascicularis*	Indonesia	Ilham et al., 2017
Monk parakeets *Myiopsitta monachus* (non-native)	United States	Burger & Gochfeld, 2009
Opossums *Didelphis virginiana*	Canada	DeStefano & DeGraaf, 2003
Peregrine falcon *Falco peregrinus*	United States	Cade et al., 1996
Racoons *Procyon lotor*, Stone marten *Martes foina*	United States	Bateman & Fleming 2012
Red foxes *Vulpes vulpes*	England	Baker et al. 2007
Rhesus macaques *Macaca mulatta*	Bangladesh	Jaman & Huffman, 2012
Vervet monkeys *Chlorocebus pygerythrus*	South Africa	Patterson et al., 2016, 2017 a, b
Wild turkeys *Meleagris gallopavo;* White-tailed deer *Odocoileus virginianus*; Coyotes *Canis latrans*; Black bears *Ursus americanus*	United States	DeStefano & DeGraaf, 2003
Wild boars *Sus scrofa*	Germany	Bieber & Ruf, 2005

directly affected by habitat disturbance and fragmentation, and in some cases are able to exploit, benefit and even thrive in urbanised areas (Strum 2010). However, for these generalist species, the feeding benefits associated with human-modified habitats have a tendency to lead to increases in HWC (Priston and McLennan 2013).

1.1.4 South Africa's urban-adapted non-human primates

Colonising species show adaptive patterns and may show a special ability to colonise newly available areas (Crowell 1962; Fedigan et al. 1984). In the sub-tropics of South Africa, some primate species have adapted to exploit human habitations and resources; namely the chacma baboon *Papio ursinus* (Hoffman and O'Riain 2012), the samango monkey *Cercopithecus albogularis labiatus* (Nowak, 2017) and the vervet monkey *Chlorocebus pygerythrus* (Patterson et al. 2016, 2017 a, b).

1.2 Study species

1.2.1 Species description

Cercopithecine monkeys are one of the most species-rich and broadly distributed subfamilies of primates in the world (Marini et al. 2012) and while some species are dependent on undisturbed habitats, others are among the most conspicuous primates in heavily disturbed regions (Richard et al. 1989; Rowe and Myers 2011). The family Cercopithecinae includes 12 genera and 69 species (Wilson and Reeder 2005). Eleven of these genera are distributed in sub-Saharan Africa (47 species). The remaining genus, *Macaca*, is one of the most widespread primate genera, with 22 species, ranging from Asia (21 species) to North Africa (1 species). Most cercopithecine species occur in the tropics (Albert et al. 2014), except two species *Macaca fuscata and Macaca sylvanus* in temperate areas. Most cercopithecine species (43 species) have populations confined to forested habitats, especially Asian species, while 22 species use both forest and non-forested habitats (i.e., wetlands, savanna, shrubland, grassland, rocky areas and caves) (Chatpiyaphat and Boonratana 2013). The four remaining species, all in Africa, are found completely in non-forest habitats (Albert et al. 2014). Most cercopithecine species (79%) can inhabit disturbed habitats (Albert et al. 2014), and 15% have populations in urban areas where they forage during the day, and sometimes sleep at night (Richard et al. 1989; Albert et al. 2014).

Cercopithecines display a large diversity of traits (Marini et al. 2012), however there are several that are common to most taxa and may promote disturbance-tolerance (Albert et al. 2014). In particular, behavioural and ecological flexibility in diet, home range and group size may explain their ability to thrive in transformed landscapes (Albert et al. 2014; Barrett et al. 2016). This may pre-adapt some cercopithecine species for survival in habitats with altered habitat structure, patchy resource distribution, and limited fruit resources (Isaac and Cowlishaw 2004; Barrett et al. 2016). Recent documentation of six key ecological traits associated with adaptability, and therefore disturbance-tolerance, have been identified: a diet not dominated by fruit, use of multiple vegetation types, semi-terrestrial locomotion, frequent use of cheek pouches, large and variable home ranges and variable group size (Albert et al. 2014; McFarland et al. 2014).

Vervet monkeys are the third most widely distributed primate species in Africa after humans *Homo spp.* and baboons *Papio spp.* (Skinner and Chimimba 2005; Pasternak et al. 2013). They are habitat generalists and are one of South Africa's most adaptable and bold urban-inhabiting members (Wolfheim 1983; Boulton et al. 1996; Freeman 2012; Blaszczyk 2017), regularly sleeping and foraging in office parks, along busy roads and in suburban gardens in the cities of Durban and Pietermaritzburg in the KwaZulu-Natal (KZN) Province (Wolfheim 1983; Freeman 2012). Despite increasing urban development in KZN, important ecological factors in the urban areas have allowed vervet monkeys to persist. However urban sprawl has significantly increased human interactions with them, resulting in increased conflict (Wimberger et al. 2010a, b). The reasonings for their urban persistence may include the loss of suitable natural habitat, the alternative, accessible feeding opportunities in transformed urban landscapes, and the increased availability and access to water and roosting sites within close proximity to food sources (Wrangham 1981; Wolfheim 1983; McDougall et al. 2010; Pasternak et al. 2013).

1.2.2 Impact on urban wildlife

The capture and consumption of vertebrate prey has been reported in a number of primate species (Young et al. 2012). Documented cases of cercopithecines predating on birds and their eggs include studies on baboons *Papio spp.* (Rowell 1966; Hassan 2001), macaques *Macaca spp.* (Tokuyama and Furuichi 2014), and vervet monkeys *Chlorocebus spp.* (Fedigan and Fedigan 1988) in the wild. However, accounts of predation suggest that predation on birds is more characteristics of dry (poor quality) habitats than wet ones and, within habitats, of the dry season rather than the wet season (Hausfater 1976; Cowlishaw and Dunbar 2000). Birds' nests experience higher predation rates, probably because they are easier for visually orientated predators to locate (Reidy and Thompson 2012). Reductions in the availability of alternative food sources may also cause generalist predators in transformed landscapes to adapt their diets to what is most available (Schmidt and Whelan 1999). Concern for the decline of bird populations and diversity within urban landscapes is validated, as habitat changes may lead to shortened breeding seasons with fewer nest replacement opportunities, and the ability of prey to re-nest may have a strong influence on the impacts of predation (Schmidt and Whelan 1999; Evans 2004).

1.2.3 Diet

Vervet monkeys, along with chimpanzees *Pan spp.* and baboons *Papio spp.* have the most omnivorous diet of all primates (Saj et al. 2001). They are generalists and feed on a wide range of foods including leaves, gum, seeds, nuts, grasses, fungi, fruit, berries, flowers, buds, shoots, invertebrates, bird eggs, birds, lizards, rodents, and other vertebrate prey (Saj et al. 2001). They have a preference for fruit and flowers, which are seasonal resources, and so their diet varies with fluctuations in food availability (Fedigan and Fedigan 1988; McFarland et al. 2014). Generalist primate species are known to adopt new food types in human modified environments and raiding becomes a common foraging strategy (McKinney 2011).

1.2.4 Threats and conservation

Vervet monkeys are listed as Least Concern on the IUCN Red List of Threatened Species, on Appendix II of CITES and on Class B of the African Convention on the Conservation of Nature and Natural Resources. However, they are classified as vermin in parts of their range and are actively persecuted by landowners in areas where they raid crops and interact with humans (Kingdon et al. 2008). Due to perceptions of a destructive nature based on raiding of houses and refuse, and disturbance and damage to homes, vervet monkey behaviours often lead to conflict and they are treated as pests by many urban residents, resulting in retaliatory killings in many documented cases (Wimberger et al. 2010a, b). The health, safety and welfare (economic and social) of residents may also be undermined by conflicts with vervet monkeys sharing human resources (Barua et al. 2013).

1.2.5 Pevious research on the species

Typically, the amount of knowledge of primate urban ecology stems from single troop studies (Camperio 1986; Hanya et al. 2011) and studies with large sample sizes of troops are rare (Southwick and Siddiqi 1998; Hoffman and O'Riain 2012; Hasan et al. 2013). Evidence suggests that urban-dwelling species may exhibit significantly different phenotypic traits to their wild counterparts through adaptation to human-induced pressures. It is therefore vital that urban ecology research does not attempt to resolve urban conflicts with knowledge applicable only to wild ecosystems (Ditchkoff et al. 2006). In the last few decades, numerous cases worldwide have demonstrated the far-reaching impacts of human development, and resolution has become a focus in urban areas in particular (Ditchkoff et al. 2006).

Most research on vervet monkeys has focused on wild troops (Struhsaker 1967; Pasternak 2011; McFarland et al. 2014) and to date no urban ecological studies have been conducted on them. Urban development of KZN has significantly increased human interactions with the indigenous vervet monkey *Chlorocebus pygerythrus*, and as such, the vervet monkey's urban role may be significant in human as well as urban wildlife ecologies (Fuentes and Wolfe 2002). Furthermore, they are considered urban exploiters and so knowledge of their persistence in anthropogenic environments will assist in their management and reduction in HWC. Despite the vervet monkeys' persecution in urban environments they are internationally listed as 'least concern' (Kingdon et al. 2008). However, little exists on their population numbers for any African regions nor on their ecology with anthropogenic changing land use.

1.3 Study site

The Ethekwini, Msunduzi and KwaDukuza municipalities of KZN (Ethekwini city 29°85'85. 30'', 31°02'60. 02''; Msunduzi city 29°34'48. 82'', 30°22'26. 91''; Fig. 1.1) are comprised of mosaics of natural greenbelts, conservancies (non-statutory forums that are formed by local people to manage and improve their living environments) and human-modified landscapes of varying housing density, all within informal human settlements, suburban residencies and public spaces (urban parks, markets). Despite the continued development of these municipalities, there is still a wide array of biodiversity to conserve (Roberts & Diederichs, 2002). KZN is one of the smallest provinces, yet it contains the second largest human population of the nine provinces of South Africa (Statistics South Africa, 2007). The city of Durban supports one-third of the Province's human population of ~3.01 million (Statistics South Africa Demographics Profile, 2014), as well as 60% of its economic activity (Ethekwini Municipality, 2003).

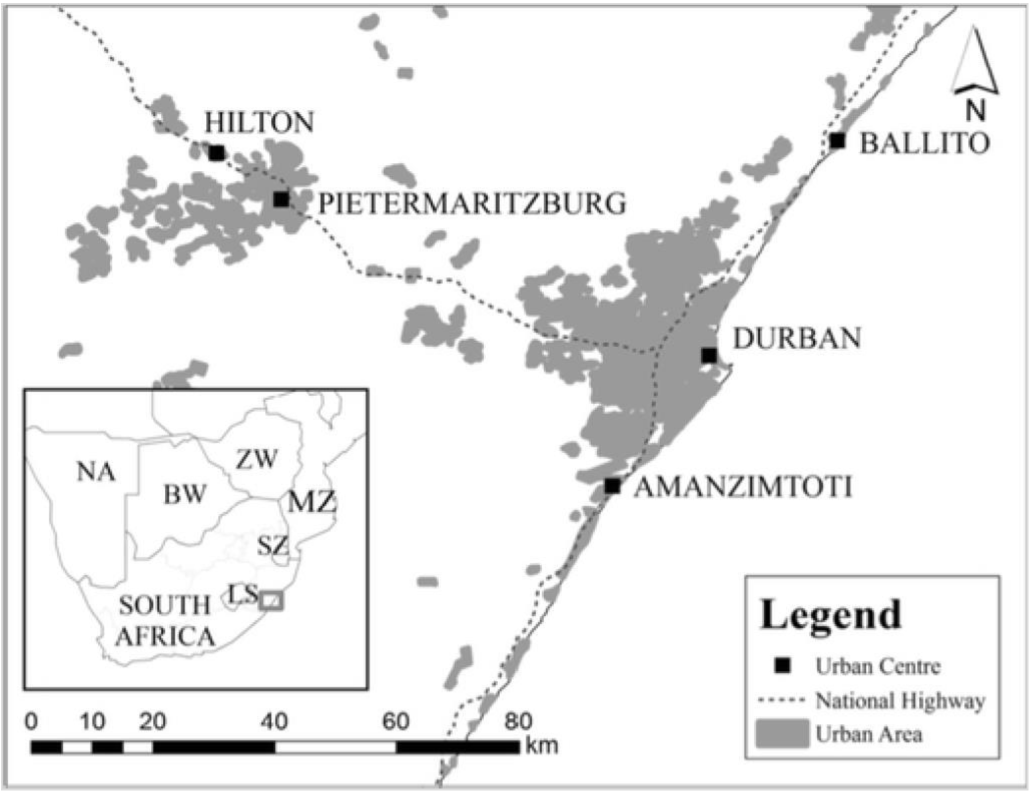

Fig 1.1. Study site covering three municipalities of the KwaZulu-Natal Province, South Africa.

1.4 Motivation and objectives of study

Urbanisation tends to manifest as limitations on freedom of movement for free-roaming animals and has become one of the most prominent threats to many wildlife species worldwide (McKinney 2008). However, despite numerous examples of wildlife alteration around South Africa's cities, relatively little urban research is being conducted to identify solutions to urban wildlife management (Cilliers and Siebert 2011). It is with this in mind that urban ecology studies have much to contribute. The overarching aim of this research was to address the limited understanding of vervet monkey urban ecology, particularly in the Ethekwini and Msunduzi municipalities of KZN, by 1) exploring human attitudes towards urban wildlife and predictors to wildlife presence 2) investigating predation using artificial nest experiments, and 3) assessing the spatial ecology of urban vervet monkey troops.

1.5 Thesis structure

The thesis is organised into six chapters: this includes an introductory chapter, four data chapters, and a synthesis chapter. Each of the data chapters contains an introduction, methods and rationale specific to the topic addressed within it so that each chapter can be read in isolation. Each of these is prepared for publication in an international, peer-review journal, so some overlap was unavoidable. I provide a summary outline of each chapter below.

In **Chapter 2** I address the key explorations of objective 1, using a survey to determine the perceptions and attitudes of urban residents towards vervet monkeys. I assess the respondents interactions with urban wildlife as a means of determining the most influential factors contributing to their attitudes.

In **Chapter 3** I address the key investigation of objective 2, using an experiment to determine the impact of urban wildlife on nesting birds.

In **Chapter 4 and 5** I address the key assessment of objective 3, using models to determine the land-use patterns of urban vervet monkey troops in KwaZulu-Natal. I assess the landscape features that are most influential in determining monkey distribution patterns and investigate the implications of these requirements for land development and vervet monkey management and conservation efforts.

In **Chapter 6** I synthesise the main thesis findings, discuss the limitations of my study, the overarching management recommendations that emerged and give motivation for future research.

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CHAPTER 2

A citizen science survey: perceptions and attitudes of urban residents towards vervet monkeys

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Abstract

A diversity of indigenous and alien wildlife persists in suburbia, and provides residents with the opportunity to experience wildlife. Suburban gardens may serve as refugia and foraging grounds for many primate species allowing them to populate within a largely urbanized landscape. However, this has led to increasing human interactions with them, resulting in conflict. Our study investigated the perceptions of suburban residents towards urban vervet monkeys *Chlorocebus pygerythrus* within the Msunduzi and Ethekwini municipalities, KwaZulu-Natal, South Africa. We assessed how these related to the monkeys' presence, activities and interactions in residential gardens, and the value of wildlife to residents. Assessment was conducted through an online questionnaire survey. General attitudes of residents to vervet monkeys were canvassed by assessing the respondents' level of active engagement in wildlife watching within their properties. We analyzed 603 surveys submitted online using logistic regression and ordinal regression models. We ascertained that vervet monkeys were disliked by 29% of residents due to their aggressiveness, destructive behaviour in gardens and households, and perceived threat to native wildlife. Frequency and duration of foraging vervet monkeys in residents' gardens was influenced by the presence of pet dogs, fruiting trees, tall trees (>2 m), ratio of indigenous to alien vegetation of gardens, residency type, and active and passive food provisioning. Despite conflict, the majority of respondents appreciated urban wildlife (67%) and actively engaged in wildlife watching (88%), emphasizing the importance of incorporating human dimension values into the management of urban biodiversity. Our study highlights the value of citizen science in providing mechanisms for identifying priority management and conservation efforts at the highly complex human-wildlife interface in an urbanized landscape.

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2.1 Introduction

Over half of the world's human population currently lives in towns and cities, and therefore for a substantial proportion of humanity, interactions with wildlife predominantly take place within an urban, human-dominated system (United Nations 2013). Human-animal relationships occur on a regular basis due to a shared history of interactions, allowing humans and wildlife to predict the others' regular behavior (Hosey and Melfi 2012) and can impact on the lives of both humans and wildlife (Waiblinger et al. 2006). Sometimes urban dwellers speak of a beneficial sense of wellbeing that comes from their interactions with urban wildlife. However, this is not always the case and feelings towards wildlife in urban environments range from tolerance and welcoming of interactions, to absolute intolerance and hatred (Hosey and Melfi 2012).

Largely because of the unavoidable presence of humans in urban areas, considerable effort is needed to understand some of the most important aspects of the urban ecosystem (Jones 2003). Community-based wildlife surveys are of most use when seeking information on the presence and abundance of easily identifiable species (Lunney et al. 1997; Kanowski et al. 2001), particularly where residents have lived in the same area for long periods of time and can therefore provide insights into changes in the abundance and diversity of local wildlife (FitzGibbon and Jones 2006). Thus, regular evaluations of community- based knowledge and attitudes are of great value when ascertaining the best approach to operate urban wildlife management programmes (Marsh 1982; Chauhan and Pirta 2010). Surveying public opinions additionally provides important clues to the content of potential conflict resolution programmes, and increases the likelihood of these being accepted and supported by the public, financially and otherwise (Decker et al. 1992; FitzGibbon and Jones 2006). There is an increasing awareness that human-wildlife conflict (HWC) resolution has tended to focus on wildlife management (Smith et al. 2006a; b), with the incorporation of human dimensions (Baruch-Mordo et al. 2009).

In urban areas of South Africa, some species have greatly expanded their range within the last five decades, including the vervet monkey *Chlorocebus pygerythrus* (Whittaker 2013). The increasing urbanization of KwaZulu-Natal (KZN) has led to a marked increase in HWC in suburban areas and further development is likely to exacerbate the levels of HWC (Wimberger et al. 2010a; b). Urban ecology research on non-human primates (hereafter referred to as 'primates') shows that the shrinking, fragmentation and conversion of primate habitats increases in human-dominated habitats (Strum 2010; Priston and McLennan 2013), and these are the primary driving forces behind human-primate conflicts and one of the greatest threats to primate survival (Laurance et al. 2002). Additionally, urbanization may compromise the conservation of urban-adapted primate species by spatially restricting and concentrating their urban populations, leading to increased intraspecies conflicts and disease transmission (Patz et al. 2004). Of greatest concern to urban wildlife management is the increased aggression towards humans that results from vervet monkeys becoming accustomed and expectant of food directly from humans (Basckin and Krige 1973; Brennan et al. 1985; Wimberger et al. 2010a; b). This behaviour has been documented in other urban-adapted monkeys in various regions of Africa (Loudon et al. 2014). As a result, vervet monkeys are common wildlife in rehabilitation centers, mainly due to their pest status and/or injury in urban areas (Wimberger et al. 2010a; b).

To further explore what factors may play a part in human attitudes towards urban wildlife, and its presence in KZN, we used an online questionnaire survey to assess the perceptions of mainly middle to high-income, suburban residents. We assessed how these related to the vervet monkeys' presence, activities and interactions in residential gardens, and the value of wildlife to residents, within the Msunduzi and Ethekwini municipalities of KZN. In particular, we were interested in urban residents' attitudes towards vervet monkeys. However, the general attitudes of residents to all wildlife was canvassed by assessing the respondents' levels of active engagement in wildlife watching within their properties. We hypothesized that there would be a range of responses concerning urban wildlife in general. Our expected predictors for negative attitudes towards vervet monkeys included the people's perception of vervet monkeys carrying possible health risks, the presence of raiding, and incidences of aggressive interactions with homeowners, their pets and/or other wildlife. We further hypothesized that the presence and behaviours of vervet monkeys' natural (foraging, feeding, interacting with wildlife) and opportunistic behaviours (raiding from homes, refuse and potentially birds' nests) in residential gardens, would be significantly influenced by specific garden characteristics, including tree presence and height, tree coverage (%), fruiting tree (presence and%), food provisioning (actively put out and passively through bird feeders), dog(s) presence, and the types of interactions vervet monkeys have with residents and their pets (aggressive/non-aggressive).

2.2 Methods

2.2.1 Study area and survey design

The Ethekwini and Msunduzi municipalities of KZN (Ethekwini city 29°85′85. 30″, 31°02′60. 02″, Msunduzi city 29°34′48. 82″ 30°22′26. 91″, Fig. 2.1) are comprised of mosaics of natural greenbelts, conservancies, and human-modified habitats of varying housing density, all within human informal settlements, suburban residences and public urban spaces, and despite the continued development of these municipalities, there is still a wide array of biodiversity to conserve (Roberts and Deiderichs

2002). KZN is one of the smallest provinces, yet it contains the second largest human population of the nine provinces of South Africa (Statistics South Africa 2007), with Durban city supporting one-third of the Province’s human population of approximately 3.012 million (South African Demographics Profile, 2014), as well as 60% of its economic activity (Ethekwini Municipality 2003). Vervet monkey presence in KwaZulu-Natal far outlives urban development within the city. However, with increased urbanization has come increased interactions between vervet monkeys and urban residents (Wimberger et al. 2010a; b), and residents deal with entire vervet monkey troops moving through their properties on a daily, weekly or monthly basis.

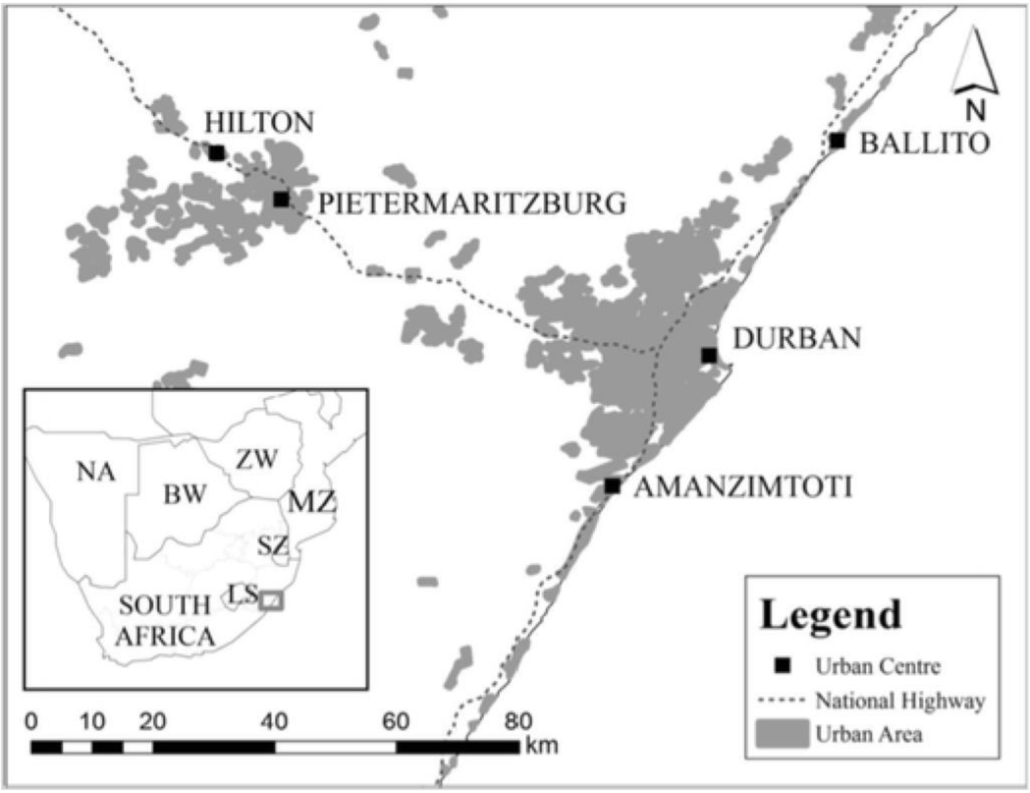

Fig 2.1. Survey area inclusive of Ethekwini and Msunduzi municipalities of the KwaZulu-Natal Province, South Africa.

From March to September 2013 a self-administered electronic questionnaire was made available for suburban residents in the Ethekwini and Msunduzi municipalities to complete online through “Survey Monkey (www.surveymonkey.com). The questionnaire’s online link was distributed widely via email circulations, newspaper advertisements, online blog posts, school newsletters and advertisements at community meetings to suburban residents of these municipalities. University of KwaZulu-Natal (UKZN) postgraduate students and staff first assessed the survey before the online link was distributed to the public. The survey had UKZN ethical clearance, which complied with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008 (Protocol number HSS/0947/012 M). Photographs of vervet monkeys were included as an appendix to the questionnaire survey to aid each respondent's identification of the species and additional effort was made to use various colloquial names along with the reference images. The questionnaire consisted of 23 multiple choice questions and six short answer questions, and was designed to take an average of 10 min. to complete and submit. Recipients were asked to complete the survey only with regard to their own properties, unless asked otherwise.

2.2.2 Direct sampling

Respondents' attitudes towards selected urban wildlife were categorized as negative (dislike or hate), positive (like or love) or neutral. The survey respondents were asked to provide data on selected predictor variables within their residences. However, it was expected that there would be a degree of error and variation in some of the submitted data on predictors, such as the ratio of indigenous to alien vegetation and the density of fruiting trees. Therefore, given that these variables were key to explaining the presence/absence and frequency of vervet monkey visitation rates, direct sampling was conducted by the principal investigator on a subset of residential gardens within the Ethekwini and Msunduzi municipalities in order to assess the confidence of the data provided.

We analyzed the respondents' attitudes towards vervet monkeys, and their presence and behaviour as functions of selected predictors chosen within the respondents' residences from responses to the online survey (Table 2.1). Ecological systems are complex and, as a result, ecological variables frequently correlate with each other. Multicollinearity can lead to invalid model results. Pearson correlation r-values, greater than 0.28 are shown to potentially bias analyses (Graham et al. 2003). Therefore, Pearson correlations were used to test for multicollinearity among predictors, with $|r| > 0.28$ set as the threshold (Graham et al. 2003). The presence/absence of tall trees (> 2 m) was correlated with indigeneous tree cover (%) ($r^2 = -0.28$), presence/absence of fruit trees ($r^2 = 0.28$), and presence/absence of garden ($r^2 = 0.4$). The presence/absence of fruiting trees in garden was correlated with vervets feeding in the garden ($r^2 = 0.34$). In such cases of multicollinearity we retained only one covariate of the correlated pairs of variables that was meaningful for the particular response in our models.

2.2.3 Statistical methods

Relations between the response and predictors (Table 2.1) were investigated based on logistic regression models. The binary response variables; presence/absence of active engagement of urban wildlife watching by respondents, vervet monkeys feeding in gardens of respondents and presence/absence of aggressive interactions between respondents and vervet monkeys were modelled with binary logistic regressions. Each response variable was modelled separately with a binomial error distribution and a logit-link function. Further on, we modeled the respondents' attitudes towards vervet monkeys, the average frequency of vervet monkey visits, the average duration of vervet monkey presence, and the frequency of vervet monkeys raiding in respondents' homes using cumulative link models (also called ordinal logistic regression models) as functions of predictors (Table 2.1). Cumulative logit models were fitted to these categorical responses with the "*clm*" function in package "ordinal" (Christensen 2013). The "convergence" and "slice" functions in package "ordinal" were used to check model convergence. All independent variables considered as having the potential to influence the dependent variables were included in the model.

We used Akaike's Information Criteria (AIC) (Akaike 1973) to evaluate the relative fit of each model via calculation of Akaike weights (Burnham and Anderson 2002), with the best models (ΔAIC $\leq$ 2) having the greatest weight. Model-averaged estimates of regression coefficients and their standard errors were calculated across models with ΔAIC $\leq$ 2 (Burnham and Anderson 2002). All statistical analyses were done in program R version 3.1.1 (R Development Core Team 2014) using other supportive packages "rJava" (Urbanek 2010), "glmulti" (Calcagno and de Mazancourt 2010) and "MuMIn" (Barton 2014). We used the package "effects" to visualize the variable effects of predictors on the responses from the top models (Fox et al. 2014).

2.3 Results

We selected the candidate models that included one or more of the selected predictors (Table 2.1) to be the final first-, second- and third-ranked models as they had lower AIC values (ΔAIC $\leq$ 2) than all other candidate models (Table 2.2). Most of the respondents (70%, n = 422) lived in suburban houses, while 23% (n = 137) lived in flats or complexes, and 7% (n = 43) lived in private housing estates acting as autonomous suburbs. One-quarter of the respondents (24%, n = 145) had already lived in their neighbourhood for two decades or more, one- fifth (21%, n = 127) for one to two decades, and over half (55%, n = 330) for one decade or less. The majority of respondents (67%, n = 404) indicated they appreciated living amongst wildlife. A few respondents (11%, n = 65) were unsure for how long they had observed vervet monkeys in their gardens, while most (79%, n = 477) had seen them in their gardens in the last decade, and a few (10%, n = 60) for more than a decade. Over half of the respondents (66%, n = 399) had dogs on their property, and half of those respondents (46%, n = 182) had interactions with vervet monkeys. A further half of those respondents (16%, n = 94) had, or knew of pets that were hurt or killed by vervet monkey(s). Around one-third of the respondents (27%, n =

Table 2.1. The predictors provided by survey respondents of the Ethekwini and Msunduzi Municipalities, KwaZulu-Natal Province, South Africa.

Measure	Definition
Garden	Presence/absence of garden in the property.
Tree coverage (%)	Percentage of tree coverage in garden.
Indigenous trees (%)	Percentage of indigenous trees in garden.
Bird feeder(s)	Presence/absence of bird feeder(s) in garden.
Birds nesting	Presence/absence of birds nesting in garden.
Time of the year birds nest	Presence/absence of birds nesting in dry season (June–August), wet season (December–February), and/or year round.
Vervets feeding	Presence/absence of vervet monkeys feeding in garden.
Food provided for vervets	Presence/absence of food provisioning for vervet monkeys in garden.
Fruiting trees	Presence/absence of fruiting trees in garden.
Tall trees (> 2 m)	Presence/absence of tall trees (> 2 m) in garden.
Trees fruiting	How long the fruiting trees in garden fruit for on average (September to February, Yearround)
Vervets hurt/killed pets	Presence/absence of incidences involving vervet monkeys injuring or killing pets, or pet's known of.
Vervets eating rubbish	Presence/absence of vervet monkeys eating from rubbish bags or bins in or near property.
Vervets raiding homes	Presence/absence of vervet monkeys raiding home, or evidence of raiding.
Health risk	Presence/absence of perceived health risk of vervet monkeys.
Vervets raiding nests	Presence/absence of vervets raiding nests in garden.
Animals interacting with vervets	Presence/absence of animals interacting with vervets in garden.

160) observed a human visitor to their residence having an aggressive interaction with vervet monkey(s) in their garden.

2.3.1 Active engagement in wildlife watching

When asked 'Do you actively engage in wildlife watching?' the majority of respondents (88%, *n* = 531) answered 'yes', with half (55%, *n* = 332) actively engaged in wildlife watching regularly. The level of active engagement was best explained by the presence/absence of indigenous trees, tree coverage (%), presence/absence of bird feeder(s), and presence/absence of nesting birds in their gardens, and two competitive models with ΔAIC ≤ 2 contained these factors (total AIC weight = 0.76; Table 2.1). The top- and second-ranked models showed that active engagement in wildlife watching increased with the presence of bird feeder(s) and birds' nesting, as well as increasing tree coverage (%) (Appendix 2.1). Wildlife watching increased with the presence of indigenous forests, but it was not significant, as respondents were unsure of the presence of indigenous forest.

2.3.2 Attitudes towards vervet monkeys

When asked 'How do you feel about vervet monkeys?' nearly a third answered 'negative' (29%, *n* = 174), nearly half answered 'positive' (44%, *n* = 267), and the remaining quarter answered 'neutral' (25%, *n* = 162). Their attitudes were best explained by the presence/absence of aggressive interactions with vervets, raiding from their residences, and beliefs that vervet monkeys pose a health risk. Two competitive models with ΔAIC ≤ 2 contained these factors (total AIC weight = 0.78; Table 2.2). The top- and second-ranked model predictors showed that negative attitudes by respondents increased significantly with the presence of aggressive interaction(s), beliefs that monkeys pose a health risk, and observed raiding of residences. However, neutral attitudes increased significantly with increasing uncertainty of whether or not vervet monkeys pose a health risk, and positive attitudes increased significantly with the absence of observed raiding of residences (Appendix 2.2). Respondents additionally cited the local vervet monkeys' perceived population growth and negative impact on urban birdlife as concerns.

2.3.3 Observed frequency and duration of vervet monkey visitations

When asked "How frequently do vervet monkeys visit your garden on average?' a few respondents answered 'on a monthly basis' (9%, *n* = 52), the majority answered 'on a weekly or daily basis' (70%, *n* = 425), and the remaining one- fifth were unsure (21%, *n* = 126). The average frequency of observed vervet monkey visits was best explained by the presence/absence of dogs, tree coverage (%) and the time of year birds were seen nesting in the respondents' gardens.

Three competitive models with ΔAIC ≤ 2 contained these factors (total AIC weight = 0.74;

Table 2.2. The top ranked models of factors influencing 1) the active engagement of urban wildlife watching by respondents, 2) the respondents' attitudes towards vervet monkeys, 3) the average frequency of vervet monkey visitations, 4) the average duration of vervet monkey visitations, 5) the presence of vervet monkeys feeding, 6) the presence of vervet monkeys raiding, and 7) the aggressive interactions between respondents and vervet monkeys in urban areas of the KwaZulu-Natal Province, South Africa.

Models	**df**	**logLik**	**AICc**	**ΔAICc**	***wi***
1. Active engagement in wildlife watching*					
Garden + tree coverage (%) + indigenous trees + bird feeder(s) + birds nesting	13	192.75	412.12	**0.00**	**0.51**
Indigenous trees + bird feeder(s) + birds nesting	7	199.69	413.56	**1.44**	**0.25**
2. Respondents' attitudes towards vervet monkeys					
Aggressive interactions + health risk + vervets raiding nests + vervets raiding houses	12	894.43	1813.38	**0.00**	**0.51**
Aggressive interactions + health risk + vervets raiding houses	11	896.09	1814.64	**1.26**	**0.27**
3. Average frequency of vervet monkey visits					
Dog(s) + tree coverage (%) + time of year birds are nesting	10	616.31	1253.06	**0.00**	**0.37**
Dog(s) + tree coverage (%)	7	620.05	1254.33	**1.27**	**0.19**
Dog(s) + time of year birds are nesting	7	620.11	1254.44	**1.38**	**0.18**
4. Average duration of vervet monkey visits					
Provisioning for vervets + fruiting trees (%) + vervets feeding	10	712.84	712.59	**0.00**	**0.38**
Birds nesting + provisioning for vervets + fruiting trees (%) + vervets feeding	11	712.46	1447.44	**1.33**	**0.20**
Bird feeder(s) + provisioning for vervets + fruiting trees (%) + vervets feeding	11	712.59	1447.71	**1.60**	**0.17**

5. Vervet monkeys feeding*					
Fruiting trees + tall trees (> 2 m)	3	216.00	438.05	**0.00**	**0.45**
Dog(s) + fruiting trees + tall trees (> 2 m)	4	215.41	438.90	**0.86**	**0.29**
6. Vervet monkeys raiding					
Fruiting trees + vervets eating rubbish	5	751.11	1512.33	**0.00**	**0.37**
Fruiting trees + dog(s)	5	751.45	1513.01	**0.68**	**0.26**
Bird feeder(s) + fruiting trees + vervets eating rubbish	6	751.06	1514.26	**1.94**	**0.14**
7. Aggressive interactions*					
Attitudes towards vervets + dog(s) + animals interacting with vervets + vervets hurt/killed pets + vervets eating rubbish + vervets raiding house	13	285.94	598.5	**0**	**0.65**

Table 2.2). The top-ranked model predictors showed that observed vervet monkey visitations decreased significantly with increasing presence of dogs and decreasing tree coverage (%) in respondents' gardens. However, observed vervet monkey visitations increased significantly with increased observations of birds' nesting in gardens during summer (wet season) (Appendix 2.3).

When asked 'How long do vervet monkeys stay in your garden on average?' half of the respondents answered 'a few minutes' (50%, $n = 303$), one-third answered 'a few hours' (33%, $n = 199$), a handful answered 'half the day' (2%, $n = 14$), and some were 'unsure' (14%, $n = 87$). The average duration of observed vervet monkey visits was best explained by the presence/absence of actively provisioned food, fruiting trees (%), and the observed presence/absence of vervet monkeys feeding in respondents' gardens. Three competitive models with ΔAIC ≤ 2 contained these factors (total AIC weight = 0.75; Table 2.2). The top- ranked model showed that the duration of observed visitations by vervet monkeys increased significantly with the increasing presence of active food provisioning, fruiting trees and observations of vervet monkeys feeding in respondents' gardens (Appendix 2.4).

2.3.4 Observed feeding and raiding by vervet monkeys

When asked 'Do vervet monkeys feed in your garden?' Most of the respondents (90%, $n = 543$) answered 'yes'. One-third (30%, $n = 181$) reported vervet monkeys feeding in their gardens on a daily basis. Observed feeding in gardens was best explained by the presence of fruiting trees and tall trees (> 2 m), and two competitive models with ΔAIC ≤ 2 contained these factors (total AIC weight = 0.74; Table 2.2). The top- and second-ranked models showed that observations of vervet monkeys feeding increased significantly with the increasing presence of fruiting trees and tall trees (> 2 m) (Appendix 2.5).

When asked 'Have you ever seen vervet monkeys raiding from inside your home, or evidence of stealing?' the majority of the respondents answered yes (73%, $n = 442$). Vervet monkey raiding was best explained by the presence of fruiting trees, and three competitive models with ΔAIC ≤ 2 contained this factor (total AIC weight = 0.62; Table 2.2). The top, second- and third-ranked models showed that observations of vervet monkeys raiding homes increased significantly with the presence of fruiting trees and observations of vervet monkeys eating refuse from bins/bags on or outside properties. In addition, observations of vervet monkeys raiding homes decreased significantly with the absence of dog(s) in respondents' gardens (Appendix 2.6).

2.3.5 Supplemental food provisioning and aggressive interactions between respondents and vervet monkeys

When asked 'Is food put out for the vervet monkeys in your garden?' some respondents answered yes

(10%, *n* = 59), however the amount was deemed too small to be significant to the overall analyses. When asked 'Have you ever had an aggressive interaction with a vervet monkey?' just under one-third of respondents answered yes (27%, *n* = 160). The presence of aggressive interactions between respondents and vervet monkeys was best explained by their attitude towards vervet monkeys, the presence/absence of vervet monkeys interacting with other animals, incidents of pets being hurt or killed by vervet monkeys, vervet monkeys feeding from refuse bins/bags in or just outside properties, and raiding from the respondent's homes. Two competitive models with ΔAIC ≤ 2 contained these factors (total AIC weight = 0.91; Table 2.2). The top-and second-ranked models showed that the incidence of aggressive interactions with vervet monkeys increased significantly with increasing negative attitudes of respondents towards vervet monkeys, observed interactions between vervet monkeys and other animals (wildlife and pets), incidences of pets being hurt or killed by vervet monkeys, observations of vervet monkeys eating from rubbish bins/bags on or near respondents' properties, and observations of home raiding by vervet monkeys. In contrast, the incidence of aggressive interactions decreased significantly with increasing positive attitudes of respondents towards vervet monkeys and decreasing observations of home raiding by them. In addition, incidences of aggressive interactions with vervet monkeys may potentially decrease with increasing dog(s) presence, with dogs acting as barriers. However, dog(s) presence was not found to be a significant influential predictor (Appendix 2.7).

2.4 Discussion

The majority of respondents had a level of interest in and/or concern for local wildlife. The survey was successful in gathering general demographic information about residents, their experiences with urban wildlife and their opinions of urban wildlife, in particular vervet monkey. The amount of submissions in the current study compared favorably to that reported in other community-based wildlife surveys (Mannan et al. 2004; Stewart 2011). Perceived trends in the presence and frequency of natural foraging as well as raiding by vervet monkeys were assessed through an examination of landowners' histories regarding the persistence of vervet monkey presence in their gardens, pet behaviour and observed interactions with vervet monkeys, and the degree of food provisioning and habituation of vervets at each residence.

Overall, surveyed residents expressed a high level of appreciation for native wildlife. However perceived health threats were raised and negative attitudes towards vervet monkeys were highly influenced by the level of negative interactions the respondents and/or their pets had experienced. In many cultures views of monkeys being sacred, however also being pests, overlap, leading to a love/hate relationship, in the midst of which conservation efforts must be managed (Lee and Priston 2005). The results showed that the residents' attitudes towards vervet monkeys were significantly influenced by the kind of interactions they or their pets have had with vervets in the past, particularly with aggressive interactions influencing dislike or hatred towards them. Such conflict presumably leads to a heightened awareness of the implicated species' presence, and may bias residents' reports of their impacts in their area. The respondents' attitudes were a function of the degree of contact with vervet monkeys as pests. Research has shown that contact with monkeys in the absence of home damage or risks tends to promote positive attitudes (King and Lee 1987; Knight 1999), while even minimal experience of raiding or aggression leads to an attribution of blame that may greatly outweigh the extent of damage (Priston 2001).

2.4.1 Vervet monkey habitat preferences

Monkeys are widely distributed throughout the world and have adapted to exploit human habitation and resources (Eudey 1987; Dela 2011). Wild vervet monkeys are habitat generalists with their only limiting factors seeming to be water availability and roosting tree presence (Wolfheim 1983; Pasternak et al. 2013). By quantifying the number of trees within each respondent's garden into a categorical density range, we were able to see that the predictors of observed vervet monkey presence by respondents showed favoritism for urban gardens with larger amounts of taller trees. Dogs, humans and birds of prey are predators of urban vervets (Zinner et al. 2002) and therefore the vervet monkeys'preference for taller trees may be for predator avoidance, as has been found in previous studies (Enstam and Isbell 2004). Wild vervet monkeys roosting in trees are characteristically found in wooded areas, with trees averaging at 7.7 m tall, and their use of tall trees has been found to decrease their risk of predation (Nakagawa 1999). Wild troops have also shown preferential use of areas with tall food plants both for predator avoidance, as well as consumption (Chapman 1987). Their habitat preference corroborates with our earlier study that showed 79% of artificial nests were depredated by vervet monkeys in winter and in areas with less canopy cover (Patterson et al. 2017). Vervet monkeys, along with baboons *Papio spp.* and chimpanzees *Pan spp.*, are the most omnivorous of primates, yet they have a dietary preference for indigenous, seasonal fruits and flowers (Fedigan and Fedigan 1988). In this study we found that the frequency and duration of vervet monkey visits increased with increasing indigenous vegetation in gardens, as well as higher densities of fruiting trees, further supporting this.

2.4.2 Vervet monkey food provisioning and raiding

Because of the biological, phylogenetic, and behavioral overlaps between humans and vervet monkeys, the relationship between the two groups has a special significance (Fuentes 2006), and provisioning by people who seek contact with urban wildlife is often a causal factor of human-wildlife conflict, particularly with monkey species, which are known to develop a taste for human foods, lose their fear of humans, and then become proactive (sometimes aggressive) in seeking them out (Brennan et al. 1985; Fa and Lind 1996). In urban and agricultural settings, vervet monkeys are found to be less subject to nutritional stress that comes from fluctuations in seasonal food availability as they have become reliant on sources of food provisioned by humans, including cultivated fruits, vegetables and crops (Saj et al. 2001). Raiding is integral to the ecology of primates inhabiting areas of human-animal interface and the cercopithecoids, most notably macaques *Macaca spp*., vervet monkeys, and baboons *Papio spp.* are frequent culprits (Naughton-Treves 1998; Fuentes 2006). This is in all likelihood due to their generalized diet and adaptive qualities; they are all opportunistic frugivores with enhanced intelligence and manipulative capabilities (Gautier and Biquand 1994). When natural foods are limited, high quality, easily digested human foods provide an alternative source of nutrition for monkeys, and raiding may intensify (Horrocks and Baulu 1994; Hoffman and O'Riain 2012). Rainfall, season, wild food variety and availability, garden characteristics, and home protection methods are all known to impact on raiding (Mohnot 1971; Hill 1997) and the raiding frequency and intensity feeds back into the attitudes urban residents hold towards these co-inhabitants. This community-based urban wildlife survey has shown that citizen science contributes to the understanding and promotion of rigorous research and monitoring of ecosystems, but also the need to interpret this information with the knowledge that attitudes are influenced by individual experiences. Despite numerous examples of wildlife alteration around South Africa's cities, further urban research is needed to identify solutions to urban wildlife management (Cilliers and Siebert 2012).

2.4.3 Conclusions

Several garden characteristics were found to influence vervet monkey presence, including the presence of tall trees (> 2 m), fruiting trees, bird feeder(s), higher tree coverage (%), indigenous vegetation (%), and the absence of dogs, within urban gardens. These garden characteristics help in urban landscape planning and management to help minimize the tension between humans and problem animals. Knowledge of the human dimensions of human-wildlife conflict may additionally help equip us with more effectively targeted management strategies, promoting peaceful coexistence between urban wildlife and people. This wildlife survey also indicates that there are residents of KZN who appreciate and value local urban wildlife, and therefore it is important that residents develop an understanding of what steps may be necessary to minimize aggressive interactions and raiding events, and encourage peaceful co-existence. Where conflict levels are too high and/or the absence of vervet monkeys is desired, adjustments to the landscape may discourage vervet monkey presence. Incorporating human dimension issues into urban spatial ecology studies will be particularly important for the future management of habitat fragments and wildlife in urban areas of KZN.

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Appendix 2.1.

Model-averaged coefficients of the top binary logistic regression models for factors influencing wildlife watching and engagement by respondents in KwaZulu-Natal Province, South Africa.

	Estimate	**Std. Error**	**Adjusted SE**	**z value**	**p (>|z|)**
(Intercept)	0.773	51.766	51.872	0.015	0.988
Garden (Present)	1.065	0.766	0.768	1.387	0.166
Tree coverage (10–20%)	0.519	0.378	0.379	1.369	0.171
Tree coverage (20–50%)	0.914	0.389	0.390	2.345	0.019*
Tree coverage (50–70%)	1.553	0.558	0.560	2.779	0.006**
Tree coverage (Not sure %)	1.335	0.691	0.693	1.927	0.054
Tree coverage (Over 70%)	1.368	1.082	1.085	1.261	0.207
Indigenous trees (0%)	1.236	0.914	0.916	1.350	0.177
Indigenous trees (50%)	0.258	0.497	0.498	0.518	0.605
Indigenous trees (80%)	0.080	0.523	0.524	0.152	0.879
Indigenous trees (Not sure %)	1.410	0.458	0.459	3.071	0.002**
Birds nesting (Present)	0.658	0.283	0.283	2.323	0.020*
Birds nesting (Present)	0.595	0.294	0.294	2.024	0.043*

Significance codes: P < 0.001 ***, 0.01 **, and 0.05 *

Appendix 2.2.

Model-averaged coefficients of the top ordinal logistic regression models for factors influencing the attitudes of respondents to vervet monkeys in KwaZulu-Natal Province, South Africa.

	Estimate	**Std. Error**	**Adjusted SE**	**z value**	**p (>|z|)**
Dislike|hate	1.218	0.391	0.391	3.111	0.002**
Hate|like	0.719	0.388	0.388	1.851	0.064
Like|love	0.573	0.388	0.388	1.477	0.140
Love|neutral	1.379	0.391	0.392	3.520	0.000***
Vervets pose health risk (Not sure)	1.184	0.466	0.467	2.532	0.011*
Vervets pose health risk (Yes)	0.718	0.181	0.182	3.955	0.001***
Vervets raiding birds’ nests (Yes)	0.353	0.194	0.195	1.814	0.070
Aggressive interactions with vervets (Yes)	0.342	0.187	0.187	0.1832	0.070
Vervets raiding houses (Occasionally)	0.596	0.368	0.368	1.619	0.106
Vervets raiding houses (Once)	0.551	0.400	0.401	1.375	0.170
Vervets raiding houses (Weekly)	0.059	0.418	0.419	0.141	0.890
Vervets raiding houses (No)	0.916	0.386	0.387	2.368	0.018*

Significance codes: $P < 0.001$***, 0.01**, and 0.05*

Appendix 2.3.

Model-averaged coefficients of the top ordinal logistic regression models for factors influencing the average frequency of vervet monkey visits to respondents'gardens in KwaZulu-Natal Province, South Africa.

	Estimate	**Std. Error**	**Adjusted SE**	**z value**	**p (>|z|)**
Daily|monthly (Presence of vervet monkeys)	1.096	0.600	0.600	1.856	0.063
Monthly (Presence of vervet monkeys) (No)	0.670	0.600	0.600	1.137	0.256
No|weekly|biweekly (Presence of vervet monkeys)	0.215	0.600	0.600	0.366	0.714
Dog(s) (yes)	0.401	0.200	0.200	2.197	0.028*
Tree coverage (%) (21–50)	0.281	0.240	0.240	1.191	0.234
Tree coverage (%) (Unsure)	0.323	0.401	0.402	0.805	0.421
Tree coverage (%) (0–20)	0.609	0.230	0.230	2.667	0.008**
Time of year birds' nesting (Unsure)	0.500	0.500	0.500	1.054	0.300
Time of year birds' nesting (Wet season)	0.900	0.500	0.500	1.881	0.100
Time of year birds' nesting (Year round)	0.440	0.500	0.500	0.885	0.400

Significance codes: $P < 0.001$***, 0.01**, and 0.05*

Appendix 2.4.

Model-averaged coefficients of the top ordinal logistic regression models for factors influencing the average duration of vervet monkey presence in the respondents'gardens in KwaZulu-Natal Province, South Africa.

	Estimate	**Std. Error**	**Adjusted SE**	**z value**	**p (>|z|)**
A few minutes|a few hours (Duration of vervet monkey presence)	1.125	0.369	0.369	3.046	0.002**
A few minutes|an hour (Duration of vervet monkey presence)	0.039	0.363	0.364	0.108	0.914
Half an hour|an hour (Duration of vervet monkey presence)	0.938	0.370	0.369	2.545	0.011*
Half an hour|half a day (Duration of vervet monkey presence)	4.273	0.454	0.456	9.382	< 2e ***
Fruiting trees (%) (Less than a quarter)	0.383	0.284	0.284	1.346	0.178
Fruiting trees (%) (More than half)	0.944	0.600	0.557	1.695	0.090
Fruiting trees (%) (Not sure)	0.061	0.283	0.284	0.216	0.829
Provisioning (Yes)	0.740	0.300	0.259	2.851	0.004**
Vervets feeding (Not sure)	0.752	0.320	0.321	2.343	0.019*
Vervets feeding (Yes)	0.700	0.215	0.215	3.197	0.001**
Birds nesting (Yes)	0.168	0.188	0.188	0.891	0.373
Bird feeder(s) (Yes)	0.130	0.164	0.165	0.767	0.443

Significance codes: $P < 0.001$***, 0.01**, and 0.05*

Appendix 2.5.

Model-averaged coefficients of the top binary logistic regression models for factors influencing vervet monkeys feeding in gardens of respondents in KwaZulu-Natal Province, South Africa

	Estimate	**Std. Error**	**Adjusted SE**	**z value**	**Pr(>|z|)**
(Intercept)	0.653	0.470	0.472	1.384	0.166
Fruiting trees (Present)	1.561	0.258	0.258	6.049	< 2e16***
Tall trees (> 2 m) (Present)	1.266	0.392	0.393	3.221	0.001**
Dog(s) (Present)	0.306	0.275	0.276	1.110	0.267

Significance codes: P < 0.001***, 0.01**, and 0.05*

Appendix 2.6.

Model-averaged coefficients of the top ordinal logistic regression models for factors influencing the frequency of vervet monkeys raiding in the respondents’homes in KwaZulu-Natal Province, South Africa.

	Estimate	**Std. Error**	**Adjusted SE**	**z value**	**p (>|z|)**
Occasionally|once (Presence of vervet monkeys)	0.391	0.234	0.234	1.670	0.095
Once|never (Presence of vervet monkeys)	0.227	0.230	0.230	0.984	0.325
Weekly|never (Presence of vervet monkeys)	1.735	0.245	0.245	7.088	<2e 16***
Vervets eating rubbish (Present)	0.328	0.157	0.157	2.085	0.037*
Fruiting trees (Present)	0.369	0.169	0.169	2.183	0.029*
Dog(s) (present)	0.280	0.169	0.169	1.653	0.098
Bird feeder(s) (Present)	0.068	0.159	0.159	0.429	0.668

Significance codes: *P* < 0.001***, 0.01**, and 0.05*

Appendix 2.7.

Model-averaged coefficients of the top binary logistic regression models for factors influencing aggressive interactions between respondents and vervet monkeys in KwaZulu-Natal Province, South Africa.

	Estimate	**Std. Error**	**Adjusted SE**	**z value**	**p (>|z|)**
(Intercept)	0.121	0.582	0.583	0.207	0.836
Vervets raiding (Occasionally)	1.064	0.498	0.5	2.13	0.033*
Vervets raiding (Once)	1.629	0.571	0.572	2.848	0.004**
Vervets raiding (Weekly)	0.156	0.56	0.561	0.277	0.782
Vervets raiding (Absent)	1.693	0.547	0.548	3.091	0.002**
Vervets eating rubbish (Present)	0.575	0.219	0.22	2.626	0.009**
Dog(s) (Present)	0.385	0.235	0.235	1.639	0.101
Attitude towards vervets (Hate)	0.849	0.393	0.394	2.153	0.031*
Attitude towards vervets (Like)	0.632	0.292	0.293	2.16	0.031*
Attitude towards vervets (Love)	1.028	0.366	0.367	2.803	0.005**
Attitude towards vervets (Neutral)	0.484	0.293	0.294	1.649	0.099
Animals interact vervets (Present)	0.747	0.22	0.221	3.387	0.001***
Vervets hurt/killed pets (Present)	0.848	0.275	0.276	3.077	0.002**
Bird feeder(s) (Present)	0.191	0.21	0.21	0.907	0.364

Significance codes: *P* < 0.001***, 0.01**, and 0.05*

CHAPTER 3
Predation of artificial bird nests in suburban gardens of KwaZulu-Natal, South Africa

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Abstract

As urbanization increases, the identification of nest predators becomes important for avian conservation and management of urban wildlife communities. We investigated bird nest predation using artificial nests in urban areas of the KwaZulu-Natal (KZN) Province of South Africa. From June 2013 through February 2014 we installed seventy-five artificial nests in 25 suburban gardens in the Ethekwini and Msunduzi municipalities of KZN. *Euplectes spp.* nests were used and baited with two quail-sized, hand-made, silicon eggs. These were placed in residential gardens and monitored by camera traps for 2-weeks in winter, spring and summer respectively. Generally, bird nesting occurs throughout the year in KZN's subtropical climate, with some avoidance during the autumn season. Therefore, experiments were not conducted during autumn, as fresh nests were not available for use. Overall the rate of predation on artificial nests was 25 % (*n* = 19), with vervet monkeys *Ceropithecus aethiops pygerythrus* predating 20 % (*n* = 17) of the nests while domestic cats *Felis catus* predated 3 % (*n* = 2) of nests. Nest predation was significantly higher in the winter season, with 79 % of depredations occurring in winter (*n* = 15), 16 % in spring (*n* = 3) and 5 % in summer (*n* = 1), and in areas with less canopy cover. Our results suggest that vervet monkeys may have a negative impact on nesting birds in urban environments. However, in order to assess the rate of predation experiments on natural nests coupled with information on fledgling success is deemed necessary to investigate avian population declines.

Keywords Nest predation. Vervet monkey. Predation rate. Urbanisation. Domestic cat.

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3.1 Introduction

Urbanisation causes varying degrees of alteration to animal diversity and abundance (McKinney 2002). Consequently, anthropogenic alterations to an ecosystem may create an environment in which population dynamics are more sensitive to predation (Evans 2004; Rodewald et al. 2011) and as a result predation may alter bird communities through potential differing nest types and body sizes (Stracey and Robinson 2012). Declines in bird populations and diversity through human intervention have become important conservation concerns (Gering and Blair 1999; Steyn 2014). Nest predation is the most frequent cause of nest failure (Ricklefs 1969; Clark and Martin 2007). Although certain bird species benefit from the urban habitat characteristics, in particular low predator diversity, high food availability and abundant nest sites (Marzluff 2001; McKinney 2002), others are susceptible (Beckerman et al. 2007).

The suburban matrix may provide heterogeneous habitats (e.g. combination of native and invasive habitat patches, abundant anthropogenic food, built-up environment) in which potentially abundant avian nest predators persist as urban exploiters or urban pests, ranging from rodents, and birds, to larger terrestrial mammals (Thorington and Bowman 2003). Many intermediate factors also influence avian nest predation such as canopy cover, nest height, housing density, exotic plants and edge effects (Nour et al. 1993; Borgmann and Rodewald 2004; Wegge et al. 2012). Larger home ranges and higher nest visibility in disturbed areas may contribute to a greater probability of predators in locating avian nests as nests are more visible from longer distances and more easily accessible (Michalski and Norris 2014). While there is support for higher nest predation in fragmented forests in central Africa (Spanhove et al. 2009; Newmark and Stanley 2011), one study found lower predation in a suburban environment due to the absence or reduced abundance of important nest predators from a built-up environment (Baudains and Lloyd 2007). Others documented either no difference in predator numbers and predation rates for urbanised versus wild areas (Melampy et al. 1999; Reidy et al. 2008). For at least some nest predators, including cats and birds of prey, predator abundance was higher in urban habitats (Marzluff 2001; Sorace and Gustin 2009), which led to the increased nest predation (Sperry et al. 2008).

Of the mammal species predating on birds' nests, monkeys and cats (domestic and feral) (Loss et al. 2013; Skinner and Skinner 1974; Cronje 2013) are common culprits. Non-human primate species (hereafter referred to as 'primates') like the vervet monkeys are generalist feeders (Saj et al. 2001) that have adapted to new food types in human-modified environments, following which, raiding often becomes a common foraging strategy (McKinney 2011). These are possible drivers of increases in monkey visitation rates in urban areas during the past few decades. Anecdotal eyewitness accounts of vervet monkeys predating on birds and their young, including weaver *Ploceus spp.* nests, were documented in urban areas of KZN. Therefore, vervet monkey density, in conjunction with the variation in seasonal food availability, and decreasing diversity in urban predators, may lead to urban bird eggs being sought out as a high protein food source, as observations have shown that monkeys learn to use a new resource due to close and regular contact with it (Bicca-Marques et al. 2009). In addition, cats are also a significant threat to urban birdlife (Molsher et al. 1999; Bonnington et al. 2013).

Currently, there is little empirical support that nest predation pressure in the urban environment is high or low. One of few studies that have gained some weight in literature is the predator refuge hypothesis, which proposes that a lower rate of nest predators in urbanized areas reduces the rate of nest predation and leads to the increased success of some urban bird species (Gering and Blair 1999; Stracey 2011). However, some studies have documented no difference in predator numbers and predation rates for urbanised versus wild areas (Melampy et al. 1999; Reidy et al. 2008). For at least some nest predators, including cats and bird of prey species, predator abundance was found to be higher in urban habitats (Marzluff 2001; Sorace and Gustin 2009), and increased predator abundance has led to increased nest predation (Zanette and Jenkins 2000; Sperry et al. 2008). The discrepancy between often-lower predation rates in conjunction with often-higher predator abundance in urban areas is known as the urban nest predator paradox (Shochat et al. 2006; Stracey 2011) and this mismatch is made all the more challenging by a lack of knowledge on potential nest predators' responses to urbanisation and the degree to which different predators impact on nest predation rates (Stracey 2011).

To date, no systematic studies of nest predator identity, or intensity have been conducted in KZN. We therefore tested hypotheses concerning effects of season and garden characteristics on the probability of artificial bird nest predation in suburbia. Taking into consideration that artificial nests are ignored by snakes due to the lack of scent and movement (Weatherhead and Blouin-Demers 2004), we expected mammals like vervet monkeys and domestic cats to be the main predators impacting on the nest survival of closed nest birds in suburbia, based on their generalist feeding patterns and adoption of easily accessible urban food sources (Wolfheim 1983; Bicca-Marques et al. 2009). Despite the evidence that vervet monkeys in the wild rely on close proximity to water sources and roosting sites (Wrangham 1981), within an urban context, this reliance might diminish due to more freely available permanent water sources and roosting trees in suburban gardens (Pasternak et al. 2013). We predicted that there would be a strong seasonal effect, with predation rates greater in the harsh dry winter season when canopy cover was at its lowest (Hausfater 1976; Kumara et al. 2000), and natural food is scarce.

3.2 Methods

3.2.1 Study area and experimental sites

The Ethekwini and Msunduzi municipalities of KZN (Ethekwini city 29°85′85. 30″, 31°02′60. 02″, Msunduzi city 29°34′48. 82″ 30°22′26. 91″, Fig. 3.1) are comprised of mosaics of natural greenbelts, conservancies (natural areas designated to conserve and protect natural resources), and human-modified habitats of varying housing density, all within human informal settlements, suburban residences and public urban spaces, and despite the continued development of these municipalities, there is still a wide array of biodiversity to conserve (Roberts and Diederichs 2002). KZN is geographically one of the smallest provinces, yet it contains the second largest human population of the nine provinces of South Africa, with Durban city supporting one-third of the Province's human population, as well as 60 % of its economic activity (Statistics South Africa 2007).

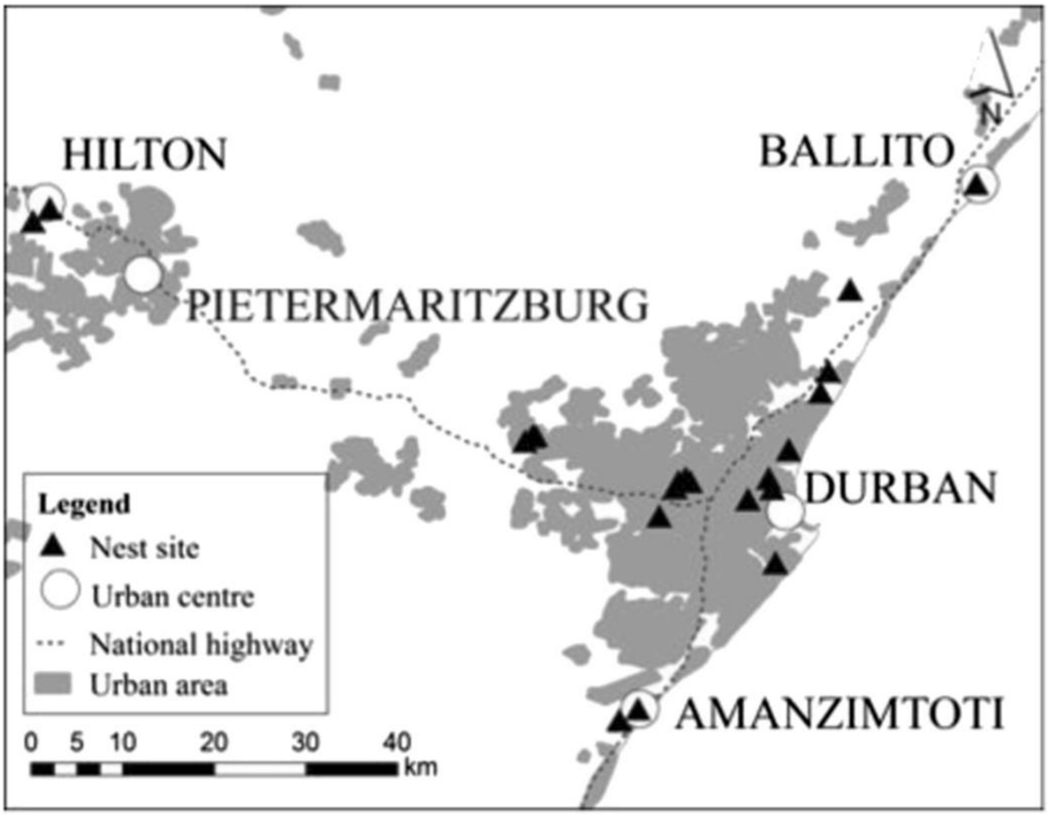

Fig. 3.1. Locations of nest sites within urban areas, inclusive of suburbs, schools and business parks, in the KwaZulu-Natal Province of South Africa.

From June 2013 to June 2014 we conducted experiments on artificial bird nest predation in 25 suburban gardens in the Ethekwini and Msunduzi municipalities of KZN (Fig. 3.2). Experiments were conducted concurrently at five sites for 2-week periods, mirroring the average 14-day incubation period of a birds' egg (Tarboton 2011), before the nests and cameras were checked, cameras removed, as well as those nests that survived, and new nests and cameras were deployed in the next set of five sites. All 25 sites were used to conduct experiments once during winter, spring and summer respectively. Generally bird nesting occurs throughout the year in KZN's subtropical climate, with some avoidance of nesting during the autumn season (Oschadleus and Underhill 2006). Therefore, experiments were not conducted during autumn, as fresh nests were not available for use. All study sites were immersed in a suburban matrix of urbanization and surrounded by conservancies. Residential gardens used as experimental sites contained both indigenous and exotic plant species, with tree coverage ranging from 5 % through to 90 %. The nest sites at each location were chosen at random.

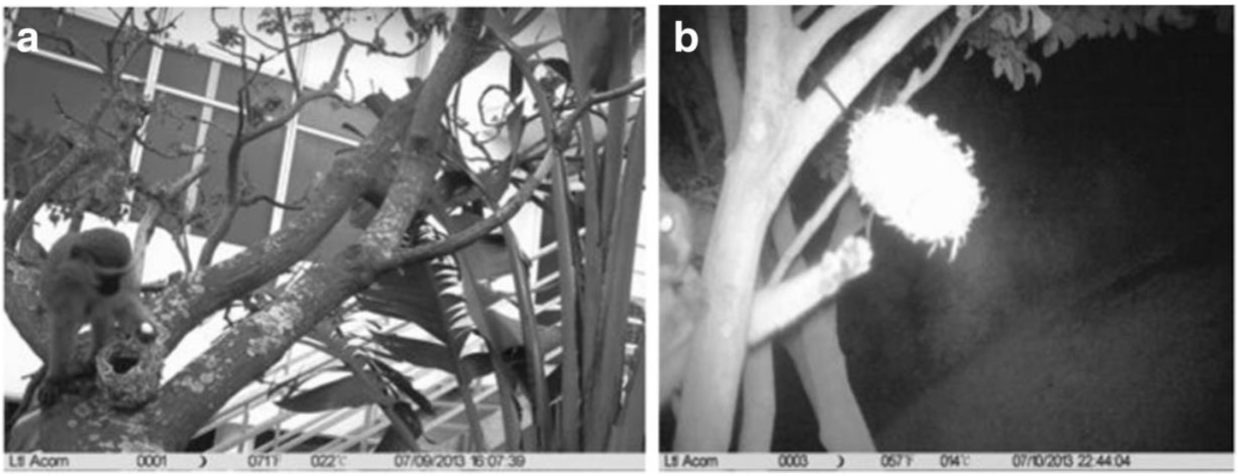

Fig. 3.2. Artificial nest predation where a. is an adult male vervet monkey investigating a nest after removing it from placement in tree, and removing an artificial egg from the nest, and b. is an adult domestic cat prior to removing a nest from placement in tree.

3.2.2 Study design

3.2.2.1 Nest predation experiments

The most commonly used method for estimating nest predation rates is the use of artificial nests as representations for real nests (Robinson et al. 2005; de Almeida et al. 2013). Artificial nests provide a relatively rapid assessment to conduct a preliminary evaluation of predation in an environment (Marini and Melo 1998; Vander Haegen et al. 2002), and considering the practical challenges of recording predation on natural nests within an urban setting, artificial nest experiments were chosen as an alternative means of identifying potential nest predators. However, artificial nests differ from natural ones in a number of important ways which may influence predation rates and predators, such as size, colour, and odour of the nest and eggs, lack of an incubating adult, and absence of nestlings (Davison and Bollinger 2000). Therefore, great effort was made to minimise as many of these differences as was practically possible within the experiments.

For several reasons, realism of the artificial setup (nest type and egg type) is important for studies that use artificial nests. Visually oriented predators may locate wicker nests more easily than real nests (George 1987; Davison and Bollinger 2000), and as artificial nests do not necessarily attract predators at the same frequency as real nests (Major and Kendal 1996; Robinson et al. 2005), natural, fresh, abandoned nests were used to maximize their similarity with real nests and real nest predation.

Weaverbirds *Euplectes spp*. were chosen as the nest predation model species for this study due to the high density of easily attainable nests throughout most of the year in KZN. Their closed nests are well structured and strategically placed to avoid predation. Only clean and undamaged abandoned nests were used, and use of these nests was within 7 days of finding the abandoned nest. Studies on predation rates on artificial and natural birds' nests show that both absolute and relative rates of predation vary depending on nest type (Zanette 2002). Therefore, the same nest type was used for every single experiment in this study, in order to avoid any bias due to differences in nest type. Nests were held in place with cable ties (1 cm × 20 cm) and placed in locations where previous nests had been found, so as to remain natural in look and placement. An effort was also made to deploy nests while no vervet monkey troops and/or domestic cats were present. In order to confirm artificial nests were placed in similar situations to those chosen by real birds, comparisons were made between nest-site characteristics of real and artificial nests. Assessments were focused on the visual conspicuousness of each nest and its height above ground. At each nest, visual estimates were made on the percentage of the nest visible from 2 m above ground from each of the four cardinal directions. We placed all nests within a height range of 2–6 m and nest height was measured from ground to the lowest point on the nest opening with a measuring tape (to the nearest cm).

Each nest was baited with two quail-sized, hand-made, silicon eggs, similar in size to weaver eggs, as use of eggs larger than those of the target species may preclude predation by small predators (Maxson and Oring 1978; DeGraaf and Maier 1996). To increase chances that artificial nests would mimic the pattern of predation observed for natural nests, the artificial eggs were made to resemble those of closed nest birds, in terms of size, colour and placement (Sieving 1992; Zanette and Jenkins 2000; Zanette 2002). In order to minimize the occurrence of predators that may have learned to associate human presence with egg availability at the nest deployment sites, we varied the direction of approach to nest sites during scheduled deployments and collections as per previous studies (Sieving 1992; Robinson et al. 2005).

3.2.2.2 Nest predator identification

We strapped a camera trap (battery powered motion-sensor Ltl Acorn 6210MMX trail camera) onto branches within 1 m of each artificial nest. These also ensured that nests were illuminated at night. In some cases, minor trimming of foliage blocking the camera's view of the nest were necessary, but performed in a manner that did not decrease nest concealment (Richardson et al. 2009; Stracey 2011). Cameras were placed at eye-level with the nest to obtain a clear view of the nest opening. Cameras monitored movements in the day and night for 13 consecutive days at each site in winter, spring and summer, respectively. Cameras were on a high passive infrared (PIR) and side PIR sensitivity setting with a sensing distance of up to 20 m and an IR light output set on high. Cameras were set to record a sequence of 3 still images, followed by a 30 s video recording, with trigger intervals set at 10 s. Time stamps recorded the serial number, moon phase, temperature, time and date of each still and video. Recordings were saved onto 32 GB SD cards, which were removed and downloaded between each camera and nest redeployment. When the nest and/or its contents disappeared we watched the videos to determine the nest fate, identified the nest predator species, and noted whether the predator removed eggs, destroyed the nest, or both. We considered the nest unsuccessful once the eggs were removed and/or the nest was destroyed. Multiple visits post-predation by the same species of predator to the same nest may have been the same individual and therefore were only counted once in each nest analysis. We excluded nests for which predator identity could not be ascertained due to camera failure and nests that failed for reasons unrelated to predation (e.g., bad weather conditions).

3.2.2.3 Predictors of nest predation

No partial brood losses were found, and the initial day of exposure to potential predation was known for all artificial nests, therefore allowing us to determine the daily survival rate for the artificial nests. Variation in rates of nest predation in relation to nest site factors (Table 3.1) including canopy cover, proximity to main road, proximity to permanent water source and proximity to natural forest were compared. These factors were chosen based on their variability across sites, and the potential for this variation to influence the presence of predator species (Wrangham 1981; Pasternak et al. 2013), and predation rates on nesting birds (Hausfater 1976; Horak et al. 2011). Breeding activity of *Euplectes spp.* was greater following increased rainfall (Ferguson 1994). Using chi-squared and Pearson product moment correlation coefficient tests, we compared predation rates of different nest sites over different seasons, using these factors. Pearson correlation tests were used to measure the strength and direction of association existing between the explanatory nest site variables. To avoid issues with collinearity among predictor variables, we removed the correlated variables ($r \geq 0.5$) using Pearson correlation co-efficient test. In this test distance to permanent water source and distance to main road were highly correlated ($r^2 = 0.81$), therefore the former was removed from further analysis. Minimum temperature was correlated with season ($r^2 = -0.84$) therefore the former was removed from further analysis. Eventually seven nest site factors were retained for modelling.

3.2.3 Statistical analysis

The count on the number of predations at each artificial nest site was converted to presence/ absence of predation, irrespective of the predator species. The three seasons were categorical variables and the rest of the explanatory variables were continuous factors (Table 3.1). We used log-transformed values of distance to road and distance to indigenous forest in our modelling to improve normality and to reduce

Table 3.1. Measures of predation and explanatory factors for each artificial nest site over the 9-month study period.

Measure	Definition
Season*	Winter, Spring, Summer
Presence or absence of predation	Count of the number of predations at each nest site recorded by a remote sensing camera.
Predation by vervet monkey	Identification and count of predations by vervet monkey recorded by a remote sensing camera.
Predation by domestic cat	Identification and count of predations by domestic cat recorded by a remote sensing camera.
Nest height (m)*	Measurement (m) recorded from ground level to nest location within tree.
Troop size*	Count of vervet monkey troop (s) passing through on a regular basis. Where troops were uncertain, distinguishing characteristics were identified for each. Where numbers were uncertain, counts were taken more frequently to determine accuracy.
Nest survival rate (days)	Count of days the individual nest survived recorded by a remote sensing camera.
Canopy cover (%)*	Four readings recorded, facing north, east, south and west of the nest site; and averaged.
Distance to water (m)	Measurement taken using GoogleEarth from GPS coordinates to the edge of water sources larger than 1 m X 1 m, as the crow flies. Only permanent water was included for distance measurements.
Distance to indigenous forest (m) (log-transformed)*	Measurement taken using GoogleEarth from GPS coordinates to the closest forest patch as the crow flies.
Distance to main road (m) (log-transformed)*	Measurement taken using GoogleEarth from GPS coordinates to the nearest main road as the crow flies.
Mean temperature (c)	Measurements taken from WeatherSA weather maps for the 2-week period nests were exposed, and the mean calculated.
Mean rainfall (mm)*	Measurements taken from WeatherSA weather maps for the 2-week period nests were exposed, and the mean calculated.

*= Independent variables retained in further analysis

the influence of large values. We applied General Linear Model (GLM) with a binomial error distribution and a logit-link function (Shaffer 2004) to investigate predictors of probability of artificial nest predation (predated =1, not predated =0) at each artificial nest as a binary response variable and all explanatory factors as predictors.

Modelling was based on the Information Theoretic Approach (Burnham and Anderson 2002), using the Akaike Information Criteria adjusted for small samples (AICc) with the best fitting model having the lowest AICc and consequently the highest Akaike weight (*wi*) (Burnham and Anderson 2002). We considered additive effects of nest site factors in our candidate models. The probability that a variable is included in the best approximating models, given the set of variables considered, was estimated by summing the *wi* of all the candidate models where the variable was included (Burnham and Anderson 2002). Multimodel inference was used to assess the shape and magnitude of the effects of predictors on predation. We considered a model competitive if the delta AIC≤2. Additionally, we used model averaging and examined coefficients and 95% confidence intervals for significance of effects across all models, based on Akaike weights (Burnham and Anderson 2002). All statistical analysis was done in Program R version 3.1.1 (R Development Core Team 2014) using packages MASS (Venables and Ripley 2002), rJava (Urbanek 2010), glmulti (Calcagno and de Mazancourt 2010) and MuMIn (Barton 2014). We used the package effects to plot variable effects on the probability of predation from the top models (Fox et al. 2014).

3.3 Results

3.3.1 Camera trapping effort

Each artificial nest and a single camera were deployed for a 14-day period for each experiment, accounting for 1050 recording days in total. Survival rates of 13 nests were unaccounted for due to cases of bad weather destroying the nests, and causing technical difficulties to the cameras. Sixty-two of the experimental recording sessions successfully captured behavioural data of urban wildlife around the artificial nests.

3.3.2 Predictors of nest predation

A total of 25 % (*n* = 19) of the artificial nests were depredated. Nest predation was by two mammalian species. Vervet monkeys were the main predators, accounting for 87 % of overall predations (*n* = 17). Domestic cats accounted for 13 % of overall predations (*n* = 2) (Fig. 3. 2). No other nest predators were recorded. Nest predation was highest during winter with 15 depredations (79 % of overall depredations). In spring three depredations occurred (16 % of overall depredations) and in summer one depredation occurred (5 % of overall depredations). Seasonality significantly influenced the rate of predation through the study period. Overall the survival rate of the artificial nests remained high at 77 % (*n* = 58). Adult male vervet monkeys performed most nest predation irrespective of season although females and juveniles of both sexes sometimes joined in investigations of nests (Table 3. 2). Younger individuals attempted to touch and sniff the nest, however dominant individuals; particularly adult males, usually removed eggs from nests. Predation involved an initial investigation of the nest entrance before eggs were identified and removed, and nests destroyed. We found no evidence of any significant relationships between nest predation and garden characteristics; however, there was a seasonal influence on the survival rate of artificial nests, with the lowest survival rate in winter during the coldest time of the year.

Table 3.2. Model selection results for the factors influencing predation on 75 artificial nests during the 9-month study period in the KwaZulu-Natal Province of South Africa.

Models	df	logLik	AICc	ΔAICc	*wi*
Winter + canopy cover	3	−29.28	64.97	0	0.42
Winter	2	−31.02	66.25	1.28	0.22
Canopy cover + nest height + rainfall + spring	5	−28.25	67.57	2.6	0.11
Canopy cover + distance to indigenous forest + rainfall + winter	5	−28.46	67.98	3.01	0.09
Canopy cover + distance to main road + rainfall + spring + summer	5	−28.53	68.13	3.16	0.09

In bold are the top models, df – Degrees of freedom, logLik – Model's Loglikelihood value
wi – Akaike weight

Table 3.3. Model-averaged coefficients for predicting nest predation on 75 artificial nests during the 9-month study period in the KwaZulu-Natal Province of South Africa.

	Estimate	Std. Error	Adjusted SE	z value	p (>|z|)
(Intercept)	−0.651	2.340	2.349	0.277	0.782
Winter	2.493	0.791	0.805	3.095	0.002**
Canopy cover	−0.020	0.012	0.012	1.684	0.092.
Spring	8.750	11.970	12.010	0.728	0.467
Nest height	0.194	0.203	0.207	0.939	0.348
Rainfall	−0.047	0.051	0.052	0.918	0.359
Distance to indigenous forest	0.266	0.323	0.330	0.806	0.420
Summer	−3.067	0.940	0.961	3.192	0.001**

Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘’ 1

Predation was best explained by winter, and two models with ΔAIC ≤ 2 contained this factor (total AIC weight = 0.64; Table 3.2). The top- and second-ranked models showed that predation increased significantly in the winter season and, with decreasing canopy cover (%) (Table 3.3, Fig. 3.3).

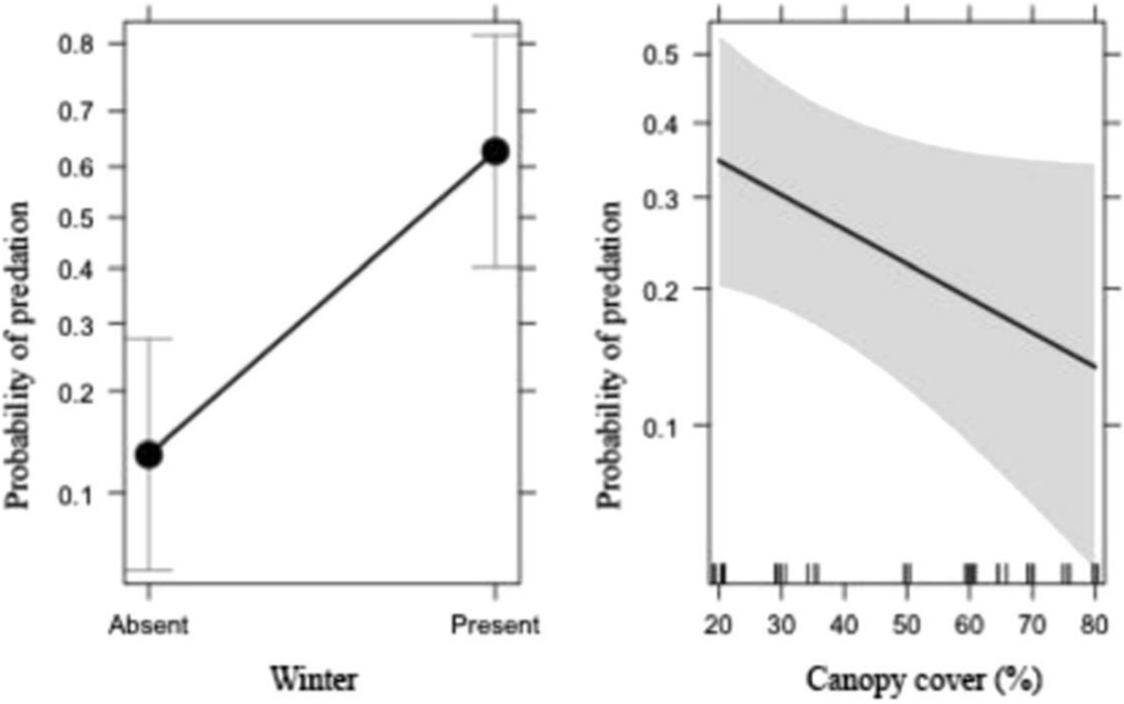

Fig. 3.3 Model-averaged estimates (±95 % confidence intervals) of top variables influencing predation rate of artificial birds’ nests as a function of winter and canopy cover.

3.4 Discussion

Our results supported all four of our predictions, and provide the first evidence that both vervet monkeys and domestic cats predate on birds’ nests in urban areas of KZN, which can be attributed to the locally increased density of generalist predators. Vervet monkeys were found to be the main predators of the artificial nests. Although we could not differentiate nest loss by vervet monkeys through predation from nests destroyed through curious behavior, the end result for nesting birds would still remain the same; vervet monkeys can negatively impact birds by predating on eggs and hatchlings and destroying birds’ nests which has been recorded within captive settings (Fairbanks and McGuire 1984), and in the wild (Skinner and Skinner 1974; Skinner and Chimimba 2005).

The capture and consumption of vertebrate prey by primate species (Young et al. 2012) and documented cases of monkeys predating on birds and their eggs include baboons *Papio spp.* (Dart 1963; Hassan 2001), macaques *Macaca spp.* (Tokuyama and Furuichi 2014), and vervet monkeys *Chlorocebus spp.* (Fedigan and Fedigan 1988). In urban settings, monkeys are subject to less nutritional stress from fluctuations in seasonal food availability, as they depend on sources of food provisioned by humans year round (Saj et al. 2001). However, the persistence of monkey species in urban ecosystems (Schwarzkopf and Rylands 1989; Schwitzer et al. 2011) is attributed to the reduction in the availability of natural food, which may cause them to adapt to what is most available (Schmidt and Whelan 1999) because of their omnivorous diet and the inclusion of exotics (Bicca-Marques and Calegaro-Marques 1994a, 1994b; Hoffman and O'Riain 2012).

In contrast to vervet monkeys, domestic and feral cats, due to their semi-domesticated status, usually avoid regulation from variable prey abundance, however their impact as pests that destroy indigenous wildlife (Nogales et al. 2004; Loss et al. 2013), and in particular birds and their nests (Woods et al. 2003; Blancher 2013) is widely documented. Furthermore, cats in residential areas have significant threats to bird eggs and nestlings (Beckerman et al. 2007; Stracey 2011). Although the human caretakers feed all domestic-owned cats in the study area, they were observed hunting natural prey during all seasons. It has been argued that cats, supported by humans, are more likely to affect prey populations than are natural predators by competing with native predators (Dickman 2009).

The probability of predation in our study was not significantly influenced by distance to indigenous forest or main roads. As vervet monkey troops living in urban areas of KZN have easy access to water and food sources within suburban gardens, they may be less reliant on the resources within indigenous forest patches along the urban greenbelt and within conservancies. Furthermore, vervet monkeys have become accustomed to traveling through residential properties in order to avoid contact with main roads wherever possible, therefore avoiding risks. The artificial birds' nests experienced higher predation rates during winter and the percentage of canopy cover negatively influenced overall nest predation at our sites, with the results demonstrating that predation of artificial nests was greater in more open areas, in accordance with previous studies (Reidy and Thompson 2012). In suburban developments with existing patches of native habitat, studies showed relatively high predation rates and increases in predation with human housing density (Jokimaki and Huhta 2000; Thorington and Bowman 2003). Although other studies have suggested that nest predation may decline with increasing urbanisation (Gering and Blair 1999; Fischer et al. 2012), this pattern may vary within and between strata in the urban gradient. Monkeys feeding on vertebrates are most often observed in challenging periods, during food shortages or winter (Hausfater 1976; Kumara et al. 2000), and of the key variables that emerged from our results, seasonality was shown to strongly influence nest predation at our sites. Accounts of predation by monkeys suggest that predation on birds are more characteristic of dry (poor quality) habitats than wet habitats and, within habitats, of the winter season rather than the summer (Hausfater 1976; Cowlishaw and Dunbar 2000). Food sources are harder to come by in KZN's dry winter months and therefore may have accounted for the increased predation events during this time of the study year, as has been documented in previous studies (Fedigan and Fedigan 1988; Schmidt and Whelan 1999).

In contrast to other studies on artificial nest predation by small primates, the artificial nests had a high survival rate in our study (Bicca-Marques et al. 2009). A low predation rate may lead to an overabundance of a few bird species that can escape predation within an urban environment. The combination of abundant predators and low predation rates suggests that urban areas may offer a refuge from predation, at least for species that can protect their nests moderately well, which may be the case for the urbanophilic *Euplectes spp*. For instance, nesting in isolated trees protects some species against monkey attacks (Robinson 1985). This may lead one to believe that vervets may be finding enough anthropogenic food sources that they do not need to bother with alternative sources of nourishment like bird nests. The same conclusion may be reached for the domestic cats, which we already established have a steady, reliable source of food from their owners. It's quite possible that high densities of *Euplectes spp. in* urban habitats are unaffected by predation while some other bird communities that are intolerant to predation may have established in non-urban habitats to escape the predation pressure (Shochat et al. 2006). Furthermore, nest predation often operates differently for bird communities in urban versus non-urban sites (Stracey and Robinson 2012).

In contrast to studies on real nests, predation rates on the nests of South African passerines tend to be substantially greater than the rate of predation in artificial nest studies (Newmark and Stanley 2011). As mentioned previously, baited artificial nests and actual bird nests differ in several ways. Artificial nest studies can still provide valuable data on nest predators (Appendix 3.1), but we must be cautious when interpreting the results since entire groups of undetected predators could also be potential predators of artificial nests. In real nests of *Euplectes spp.*, predation rates vary from egg to fledgling stage (Ferguson 1994; Pryke and Lawes 2004). Strategies by nesting birds to deter nest predators including spatial patterns of nest distribution, nest densities, and nest structures (Friedl and Klump 2000; Pryke and Lawes 2004) were some of the aspects not considered in our study. Nevertheless, we identified two nest predators that could be potential predators of real bird nests.

3.5 Conclusions

Our study provides important information on landscape management with a view to supporting avian diversity and conservation in suburban landscapes. Further studies involving the monitoring of artificial bird nests within natural environments will assist in comparisons of predation rates on artificial nests between paired urban and non-urban sites. Additionally, monitoring of natural nests will be able to confirm the extent of vervet monkey impact on the decline of some urban bird species and will assist in comparisons of predation rates on artificial versus real nests between paired urban and non-urban sites. Experiments showing how predation rates in an urban environment might differ from a non-urban environment will also give relevance to the study in a broader context. It is useful to consider that as predation rates may already be minimal, perhaps higher rates of nest predation on natural nests helps prevent dominance by only a few species. This study advocates for more detailed studies of vervet monkey dietary requirements versus what is available in an urban setting to test ideas regarding the availability of alternative food resources and how this affects nest predation. To fully understand the top-down processes, we need detailed nest predation studies that could be tested with different nest types and placement and relate it to nesting outcomes of various bird communities in urban and rural settings.

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Appendix 3.1.

A summary of studies that have examined the factors affecting predation of birds' nests by monkeys.

Reference	Species	Location	Urban/ Forest/ Captive	Predator	Distance to water	Human disturbance	Seasonality	Nest density	Nest visibility
Present study	Artificial nests using disused *Philetairus socius* nests	South Africa	Urban	*Chlorocebus pygerythrus*	X	X	X		
Bicca-Marques et al. 2014	Artificial nests with *Cortunix cortunix japonica* eggs	Brazil	Forest	*Alouatta guariba clamitans*		X			
de Almeida et al. 2013	Artificial nests	Brazil	Forest	*Callithrix pennicillata* *Callithrix jacchus*		X		X	
Alexandrino et al. 2012	*Icterus pyrrhopterus*	Brazil	Urban	*Callithrix penicillata*		X			
Bicca-Marques et al. 2009	*Gallus gallus domesticus* eggs	Brazil	Forest	*Alouatta caraya*		X			
Tarwater 2008	*Pseustes poecilonotus*	Panama	Forest	*Cebus capucinus*					X
Carter and Bright 2002	Artificial nests using disused *Ploceus cucullatus* nests	Mauritius	Forest *PA	*Macaca fascicularis*					

Ferreira et al 2002	Artificial nests	Brazil	Forest *PA	*Cebus apella*				X				
Robinson and Robinson 2001	*Pseustes poecilonotus*	Panama	Forest	*Cebus capucinus*							X	
Field et al. 1997	Artificial ground nests simulating *Colinus virginianus*	United States	Urban	*Macaca fuscata*	X		X					
Fedigan 1990	*Pionus senil*is and their eggs	Costa Rica	Forest *PA	*Cebus capucinus*					X			
Olmos 1990	*Harpiprion caerulescens*	Brazil	Forest	*Cebus apella*								X
Goodman 1989	*Stachyris nigriceps*	Malaysia	Forest *PA	*Presbytis hosei*						X		
Stearns et al. 1988	various species	United States	Captive	*Lagothrix lagotricha*		X						
Sieving pers obs.	*Artificial nests*	Panama	Forest *PA	*Cebus capucinus*					X			

PA = Protected Area

CHAPTER 4
Factors affecting vervet monkey troop size and behaviour in a suburban matrix in KwaZulu-Natal, South Africa

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Abstract

Globally with increased urban development, understanding spatial habitat requirements of urban-dwelling wildlife is increasingly important for conservation management. Consequently, we determined the factors that influence the presence of vervet monkeys (*Chlorocebus pygerythrus*) in urban landscapes. From June 2013 through May 2014 observations were conducted on vervet monkey troops in 20 suburban gardens in the Ethekwini and Msunduzi municipalities of KwaZulu-Natal, South Africa, following a standardized group scan sample method. The observation data were analyzed to determine population-level patterns of landscape use and key suburban landscape features influencing seasonal behaviour, troop size and sex ratios of vervet monkey troops. Mean troop size (29 + 3.4 (SE) individuals) was influenced by distance to water (m) and the residence type, and sex ratio varied across study sites with an average ratio of 3 adult females to each male. Higher visitation was found in suburban gardens closer to roads, and where food was provisioned. Foraging, grooming and playing increased during winter and in urban gardens with higher tree density and greater canopy cover, and decreased with increasing troop size. Resting decreased with increasing distance from indigenous forest patches and roads. Suburban gardens experienced high levels of raiding. Understanding vervet monkey spatial ecology within a transformed landscape contributes to determining sustainable ways to mitigate conflict and manage their populations in suburbia.

Keywords: Citizen science. Human-wildlife conflict. Land use patterns. Spatial ecology. Urbanisation. Vervet monkey.

4.1 Introduction

Urbanisation involves one of the most extreme forms of landscape change, in some cases leading to a complete restructuring of fauna and flora composition, and is thus a major concern in conservation biology (McKinney, 2002). In particular, local wildlife and vegetation diversity generally decline with increasing urbanisation (Lepczyk et al., 2008; McGill et al., 2015; McKinney, 2002; Villaseñor et al., 2014). Research on non-human primates (hereafter referred to as 'primates') shows that fragmentation and conversion of primate habitats increases in human-dominated landscapes (Strum 2010; Priston and McLennan 2013). These changes are the primary driving forces behind human-primate conflicts and one of the greatest threats to primate survival worldwide (Laurance et al. 2002). Additionally, urbanization may compromise the conservation of urban-adapted primate species by spatially restricting and concentrating their urban populations, leading to increased intra-species conflicts and disease transmission (Patz et al. 2004). Despite these challenges, some species are able to adapt and persist in urban ecosystems (Aronson et al., 2014; Marzluff & Rodewald, 2008). Primates display a large diversity of traits, several of which enable disturbance-tolerance. In particular, behavioural and ecological flexibility in diet, home range and group size may explain their ability to thrive in human-dominated landscapes (Albert, McConkey, Savinni, & Huynen, 2014; Marini et al., 2012). These factors may preadapt some Cercopithecine species for survival in regions with altered habitat structure, patchy resource distribution, and limited fruit resources (Isaac & Cowlishaw, 2004). Recently six key ecological traits associated with adaptability, and therefore disturbance-tolerance, were identified: a diet not dominated by fruit, use of multiple vegetation types, semiterrestrial locomotion, frequent use of cheek pouches, large and variable home ranges and variable group size (Albert, McConkey, Savinni, & Huynen, 2014).

Most research on vervet monkeys (*Chlorocebus pygerythrus*) has focused on wild troops (Pasternak et al., 2013; Struhsaker, 1967). To date few urban ecological studies have been conducted on this species. Despite increasing urban development in KwaZulu-Natal (KZN), South Africa, important ecological factors in urban areas have allowed the indigenous vervet monkeys to persist, however urban sprawl has significantly increased human interactions with them, resulting in conflict (Wimberger, Downs, & Boyes, 2010a; Wimberger, Downs, & Perrin, 2010b). Vervet monkeys are habitat generalists and regularly roost and forage in office parks, along busy roads and in suburban gardens in the cities of Durban and Pietermaritzburg in KZN (Basckin & Krige, 1973). Therefore, their urban presence may be significant in urban wildlife ecology (Fuentes & Wolfe, 2002). Despite the loss of suitable natural habitat, vervet monkey urban persistence may be a consequence of alternative and/or accessible feeding opportunities in human-dominated landscapes, and increased availability and access to water within close proximity to anthropogenic food sources, (Wolfheim, 1983; Wrangham, 1981). Negative human perceptions of urban vervet monkeys are generally based on the vervet monkeys' raiding of homes, gardens and refuse (Patterson, Kalle & Downs, 2016; 2017). This vervet monkey behaviour often leads to human-monkey conflict and with them often treated as pests by many urban residents, resulting in retaliatory killings in various documented cases (Wimberger, Downs, & Boyes, 2010a; Wimberger, Downs, & Perrin 2010b). The health, safety and welfare (economic and social) of residents may also be undermined by conflicts with vervet monkeys sharing human resources (Barua, Bhagwat, & Jadhav, 2013). Therefore, vervet monkeys stand as a model species for understanding urban wildlife persistence within the context of continued human-dominated landscape transformation.

Given the lack of knowledge, our goal was to determine whether there are specific factors that influence the presence of vervet monkeys in urban landscapes. Understanding the factors that promote the success of urban species is necessary if we are to gain an understanding of the factors that shape urban wildlife communities and provide recommendations to urban planners and concerned citizens to allow retention or enhancement of urban wildlife communities (Stracey, 2011). Studying the behavioural aspects of problem wildlife aids in managing conflict issues in urban areas. To address our goal, we sought to test five hypotheses. Firstly, we hypothesized that troop size is influenced by seasonality, residence type, proximity to permanent water sources and food provisioning. Based upon our prior vervet monkey studies (Patterson, Kalle & Downs, 2016; 2017), we predicted that troop size would be larger around suburban houses, closer to permanent water sources and where food was provisioned. Secondly, we hypothesized that the resting behaviour of vervet troops is influenced by natural factors, including the presence/absence of raptor nest(s), and man-made structures including the distance to the nearest main road. We predicted that resting would decrease with increasing distance from indigenous forest patches and main roads. Thirdly, we hypothesized that resting by vervet monkey troops would be influenced by seasons, the distance to the nearest main road (due to the relative openness), and the residence type. We predicted that resting would be higher in summer, further from main roads, and around suburban houses. Fourthly, we hypothesized that foraging by vervet monkey troops is influenced by food provisioning and bird feeders. Considering Patterson et al. (2016; 2017) we predicted that foraging would increase with food provisioning and bird feeder presence. Finally, we hypothesized that playing by vervet monkey troops is influenced by the presence/absence of a raptor nest(s), a dog(s), and the residency type. Based upon Patterson et al. (2016; 2017), we predicted that playing would be higher around suburban houses, and where raptor nests and dogs were absent.

4.2 Materials and methods

The Ethekwini and Msunduzi municipalities of KZN (Ethekwini city 29°85'85. 30'', 31°02'60. 02''; Msunduzi city 29°34'48. 82'', 30°22'26. 91''; Fig. 4.1) are comprised of mosaics of natural greenbelts, conservancies (non-statutory forums that are formed by local people to manage and improve their living environments) and human-modified landscapes of varying housing density, all within informal human settlements, suburban residencies and public spaces (urban parks, markets). Despite the continued development of these municipalities, there is still a wide array of biodiversity to conserve (Roberts & Diederichs, 2002). KZN is one of the smallest provinces, yet it contains the second largest human population of the nine provinces of South Africa (Statistics South Africa, 2007). The city of Durban supports one-third of the Province's human population of ~3.01 million (Statistics South Africa Demographics Profile, 2014), as well as 60% of its economic activity (Ethekwini Municipality, 2003).

From June 2013 through May 2014 (winter, June to August; spring, September to November; summer, December to February; autumn, March to May) observations were conducted on different urban vervet monkey troops in 20 residential gardens in the Ethekwini and Msunduzi municipalities. One free ranging troop of vervet monkeys was studied at each site (Fig. 4.1). Prior to the start of our study, great effort was made via online articles, email advertisements, and local conservancy meetings, with the intention to recruit volunteers (henceforth termed as "observer(s)") from the general public. The study sites were chosen based on the willingness and reliability of the observers who lived there, regardless of the frequency of vervet monkey presence or absence on their property. Eighteen observers were selected and trained to distinguish between adult males, adult females, juveniles and infants, and an additional trial month was employed prior to the beginning of the study period, in order for each observer to build confidence in accurate record taking and to assure that all observers recordings followed the standardized method. The principal investigator visited each site prior to commencement of the study and thereafter on a bi-monthly basis to monitor the troops and evaluate each observer's accuracy at record taking. The remaining two troops and their study sites were observed by the principal investigator who followed the same standardized method of recording as all the other observers. Vervet monkeys were classified as, adult males (possess a grey coat with long limbs, a long face and prominent, blue scrota), adult females (smaller than adult males, pelage is grey with shorter limbs and more heart shaped faces than in adult males), juveniles (12–16 months old, 25–50% in size of adults), and newborns (approximately less than 3 months old and less than half the size of yearlings) (Groves, 2001; Rowe, 1996). Sub-adults were classified with adults, as the distinction between adults and sub-adults was difficult to determine. Each vervet monkey troop had several recognizable individuals, allowing verification of group identity by each observer.

The standardized group scan sample method involved keeping an inventory of the sex, age class, and behaviour, which was recorded and categorized into foraging, playing, resting, and grooming of individual troop members (Graham, Bulloch, & Lewis, 2013; Martin & Bateson, 1993). Foraging describes the examination or manipulation of food items. Where individuals were observed feeding, identifiable food items were also recorded. Playing describes non-aggressive interactions between individual monkeys, or with objects or other species. Resting describes motionless activity, often in close proximity to other individuals. Grooming describes picking and brushing through oneself or another individual's fur, often as a social act. In an effort to avoid repeat counts of individuals, recording durations exceeding 2 minutes were avoided and, where more than one recording per day was possible, 20 minute intervals between recordings were applied. The time and date of each group scan was noted. The number of recordings per week by each observer varied from daily recordings for some observers, to three or four weekly recordings for others. In addition, breaks in record taking when observers were away for weekends and holidays, were unavoidable. Therefore, the overall mean group size was estimated by taking the mean of different group recordings for every one-week period, and group size was classified into different class intervals for better interpretation between seasons. Observations ranged from 12 to 28 days per month. Recordings were pooled for one year and analyzed to estimate the frequency distribution of group size, sex ratio, mean group size and age structure.

We restricted our analyses to areas within the boundaries of the observation sites as these areas are consistent with the extent of observable habitat characteristics (Beckmann, Murray, Seidler, & Berger, 2012). This approach assumes that observed occurrences are a subsample of available sites that inform animal habitat preferences (Klar et al., 2008; Manly, McDonald, & Thomas, 1993). This assumption is reliable since erratic movements indirectly related to habitat selection would be rare in resident troops, and, at most, would introduce random errors to the occurrence of subsamples (Klar et al., 2008). From our prior urban monkey studies (Patterson, Kalle & Downs, 2016; 2017), we identified 15 environmental characteristics as potentially important factors influencing vervet monkey distribution and behaviour during the study. The variables were mean time of the sighting, observer effort (days), season, presence/absence of raptor nests nearby, canopy cover (%), mean temperature (ºC) and mean rainfall (mm), as well as constants including distance to water (m), distance to indigenous forest patch (m), the distance to a main road (m), residency type (house, flat, complex, business park, estate), presence/absence of dog(s), presence/absence of bird feeder(s), presence/absence of raiding (theft of items from residence or residential bins) on the property, and presence/absence of supplementary food provisioning for troops by homeowners (see Table 4.1 for recording details). Each behaviour was a binary response variable (exhibited behaviour = 1, not exhibited = 0) across sites. We classified behaviour into five types: playing, foraging, grooming, resting, and feeding and modelled each of them separately. In our group scan sampling method, we recorded the behaviour of the troops based on the majority of the behaviour (five types: playing, foraging, grooming, resting, and feeding) performed by many members of the group. For example, if the majority of individuals in a troop were observed feeding within a recording session we considered the major activity to be feeding for that group in the particular time span. In this manner all behaviours were recorded and assigned as presence/absence of each behaviour type for each time span. Because of the repeated measures on the same observer and locality across the survey period, we included the observer identity and locality as random effects in all models. All other environmental variables were treated as fixed effects.

Prior to modelling, all explanatory variables were tested for multicollinearity using Pearson correlation coefficient tests ($P \geq 0.05$). We retained seasons instead of climate and rainfall as they were correlated ($r^2 \geq 0.5$). Canopy cover was correlated with presence/absence of raptor nests ($r^2 = 0.6$) hence we retained only one of the two in our models based on a priori hypothesis. We selected the environmental variables in the global model based on a priori hypothesis, only until it reached convergence and to avoid overfitting of the models. We evaluated the significance of each variable using the Wald Chi square test P-values and 95% confidence intervals (Goodman et al., 2012). We then created a candidate model set with subsets of the global model using the dredge function in program R version 3.1.1 (R Development Core Team, 2014). All statistical analyses were done in program R using other packages; *rJava* (Urbanek, 2010), *AICcmodavg* (Mazerolle, 2012), *glmulti* (Calcagno & de Mazancourt, 2010) and *MuMIn* (Barton, 2009).

We fitted generalized linear mixed models (GLMM) to evaluate the environmental factors (Table 1) affecting troop size with a Poisson distribution. Maximum likelihood estimates were derived using GLMM with Laplace approximation (Bates & Maechler, 2009) using the lmer function from the package lme4 in program R (Bates et al., 2015). We fit generalized mixed effects logistic models (Zuur et al., 2009) using the glmer function to investigate environmental factors influencing each behaviour with a logit-link function and a binomial error distribution. The best-fit models were identified using Akaike's Information Criterion for small sample sizes (AICc), showing the AICc differences and Akaike weights (*wi*) (Burnham & Anderson, 2002). Models $\leq 2\Delta$AICc were considered to have strong support (Burnham & Anderson, 2002). We used the package *ggplot2* to plot variable effects on the predicted responses (Wickham, 2009). To explore the relative contribution of the fixed and random effects combined to the overall variance explained by the top model, we used the *r. squared* GLMM function in the R package *MuMIn* which calculates the conditional R^2 (GLMM R^2 c) described by Nakagawa & Shielzeth, (2013).

4.3 Results

We observed 1036 individual vervet monkey behaviours/occurrences over the study period. Group composition changed slightly over the length of the study period due to reclassification of infants and juveniles to older age classes and newborns introduced to troops over the main breeding season. Vervet monkey troop size ranged from 17 to 53, with a mean troop size of 29 (+ 3.4, SE) (Table 4.2) and sex ratio varied across sites with an average ratio of 3 adult females to each male.

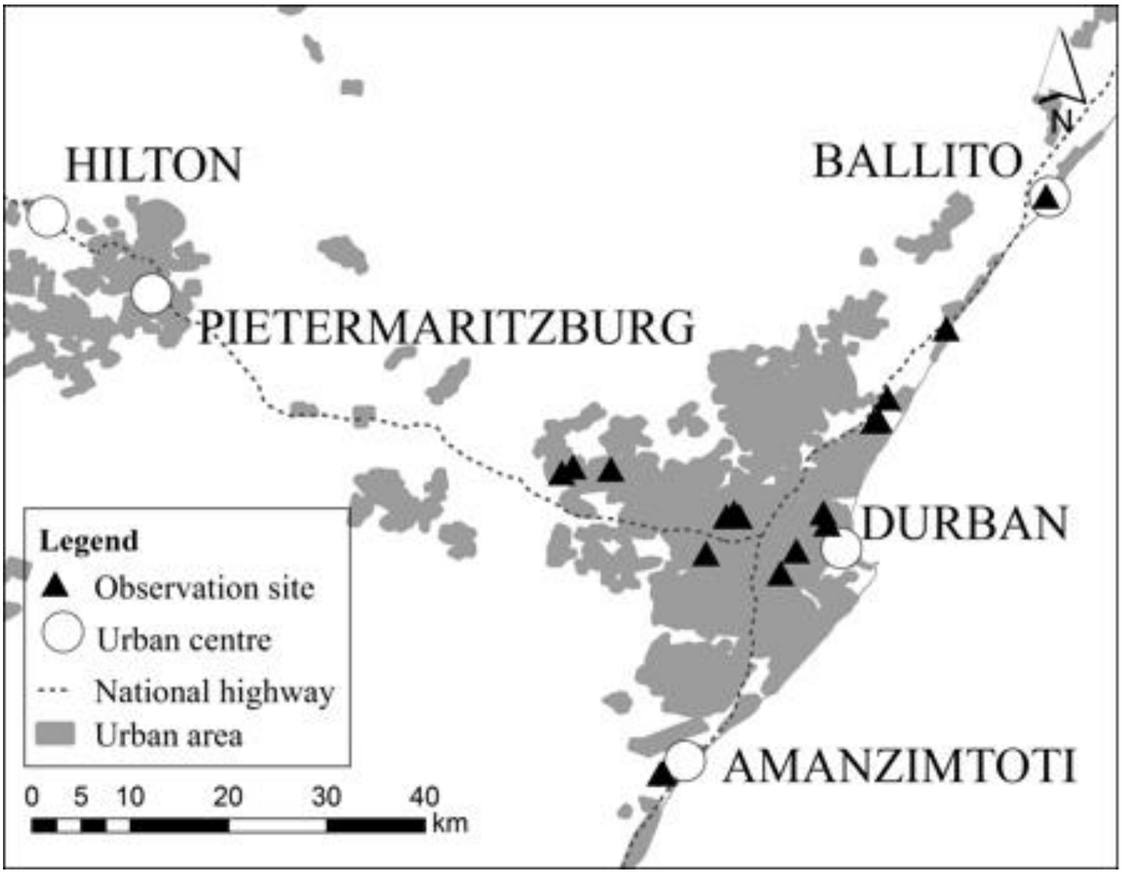

Fig. 4.1. Locations of observation sites of urban vervet monkey troops in urban areas of the KwaZulu-Natal Province, South Africa.

Table 4.1. The environmental factors recorded for each observation site in the Ethekwini and Msunduzi municipalities of the KwaZulu-Natal Province, South Africa.

Measure	**Definition**	**Response variable**				
		Troop size	Resting	Grooming	Foraging	Playing
*Mean time	Visitation times were recorded for each observation.		√	√	√	√
^Season	Winter, Spring, Summer, Autumn	√				
*Observer effort	Mean number of days spent in a month by each observer in recording the data	√				√
#Raptor nest	Presence/absence of raptor nest(s) visible from the visitation site.	√	√			√
#Bird feeder	Presence/absence of bird feeder(s) in each garden was recorded.	√	√		√	√
*Canopy cover (%)	Four readings were taken, facing north, east, south and west within the residency's garden; these were averaged.			√		
*Distance to water (m)	Measurement was taken using Google Earth from GPS coordinates to the edge of the water source as the crow flies. Only permanent water was included for distance to water measurements.	√	√	√	√	√
*Distance to indigenous forest (m)	Measurement was taken using Google Earth from GPS coordinates	√	√	√		√

	to the edge of the forest patch as the crow flies.					
*Distance to main road (m)	Measurement was taken using Google Earth from GPS coordinates to the nearest main road as the crow flies.		√	√	√	√
*Mean temperature (ºC)	Measurements were taken from South African Weather Services 2013 weather maps.					
*Mean rainfall (mm)	Measurements were taken from South African Weather Services 2013 weather maps.					
#Residency type	We recorded where the troop was observed moving through (house/flat/complex/business park/estate).	√	√		√	√
#Dog	Presence/absence of dog(s) on each residence was recorded.	√	√			√
#Raiding	Presence/absence of raiding of residence or residential bins.	√			√	√
#Food provisioning	Presence/absence of food provided for vervet monkeys by homeowners was recorded.			√	√	√

* = Continuous variable, ^ = Categorical variable, # = Binary variable, √ = Variables used in modelling the particular response

Table 4.2. Summary of the 20 vervet monkey troops observed in urban gardens of the KwaZulu-Natal Province, South Africa, including site type and observer days per month.

Troop	Location (S, E)	Site type	Observation days per month	Maximum troop size	Adult males	Adult females
1	29.470267, 30.462513	House	20	28	2	16
2	29.390931, 31.073174	Complex	12	28	2	10
3	28.572726, 31.443853	House	12	31	2	11
4	29.441292, 31.032998	House	16	24	3	15
5	30.032980, 30.515078	Complex	20	28	3	10
6	30.032569, 30.520021	House	6	19	3	9
7	29.820122, 30.931260	House	12	19	2	6
8	29.492557, 30.562841	House	28	30	5	15
9	29.491401, 31.004711	House	12	24	3	12
10	29.441102, 31.034779	Business park	20	23	2	6
11	30.404315, 30.295487	House	12	33	3	15
12	29.318930, 31.130030	House	16	53	3	20
13	29.778033, 31.038097	House	12	17	2	6
14	29.830477, 31.016476	House	20	23	3	10
15	29.402101, 31.003455	House	12	17	2	5
16	29.512724, 30.542086	House	16	45	6	14
17	29.781050, 30.817220	House	12	48	7	25
18	29.823654, 30.936234	House	20	23	2	7
19	29.715460, 31.071522	House	12	17	3	6
20	29.464311, 30.470237	House	12	45	3	20

Vervet monkey troop sizes in urban gardens were best explained by distance to water (m) and the residence type in the top model (Table 4.3). Troop size increased significantly away from water sources (Fig. 4.2a) and around suburban houses rather than complexes and business parks (Fig. 4.2b). Resting by vervet monkey troops in urban gardens was explained by distance to indigenous forest patches (m), distance to main roads (m), and raptor nest(s) present in the top model (Table 4.3). Vervet troops rested close to main roads (Appendix 4.2a), and indigenous forest patches (Appendix 4.2b), but responses appear skewed due to the weak effect of these two factors, while presence of raptor nest(s) had a relatively stronger influence (Appendix 4.2c). Grooming by vervet monkey troops in urban gardens was best explained by mean time (hours) and food provisioning in the top model (Table 4.3). Grooming increased in the afternoon (13-15 h) (Appendix 4.3a) and at sites where food was provisioned (Appendix 4.3b). Foraging by vervet monkeys in urban gardens was best explained by bird feeder(s) and raiding in the top model (Table 4.3). Foraging increased at sites where a bird feeder(s) was present (Appendix 4.4a) and decreased significantly in the presence of raiding (Appendix 4.4b). Playing by vervet monkeys in urban gardens was best explained by the presence/absence of dog(s) and bird of prey nest(s) in the top model (Table 4.3). Playing increased with the presence of a dog(s) (Appendix. 5a) and a raptor nest(s) (Appendix 4.5b). A summary of all the competitive models of troop size, resting, grooming, foraging, and playing of vervet monkey troops (Appendix 4.1), and a summary of food items fed on by vervet monkey troops across different seasons (Appendix 4.6) is presented.

4.4 Discussion

Previous studies have documented mean troop sizes of wild vervet monkeys in Africa ranging from 25 individuals (Fedigan & Fedigan, 1988; Struhsaker, 1967) to 26.6 (± 18.1, SD) (Pasternak et al., 2013). Therefore, our mean troop size of 29 (± 3.4, SE) individuals was not unusual. We found that troop size was not influenced by seasonality and food provisioning, as hypothesized, but was affected by proximity to permanent water sources and residency type. Suburban properties tend to incorporate gardens with rich resources for urban-dwelling monkey troops, accounting for larger troops observed in residences, whereas business parks are more developed with natural resources increasingly fragmented and higher risks of danger due to business park traffic and further still, housing complexes are highly developed with a high housing density and high levels of traffic. In urban settings, vervet monkeys are generally subject to less nutritional stress from fluctuations in seasonal food availability as they depend on sources of food provisioned by humans year-round, including cultivated fruits, vegetables and crops (Saj, Sicotte, & Paterson, 2001). Hence we were not surprised to find that seasonality did not directly affect troop size nor behaviour types.

The ratio of adult males to females in wild vervet monkey troops is usually 1.5 females to each male (Cheney & Seyfarth, 1990), however our study showed a higher ratio of, on average, 3 adult

Table 4.3. Fixed factors from top models influencing troop size and behaviours of vervet monkey troops in urban gardens of the KwaZulu-Natal Province, South Africa.

Response	**Variables** ***Fixed effects***	**Estimates ±SE**	**Z value**	**Pr(>|z|)**	**Chisq**	**Df**	**Pr(>Chisq)**	**R2**	**VIF**
Troop size	(Intercept)	5.24±3.20							
	Distance to water	0.02±0.01			4.063	1	0.044	0.23	1.433
	Residence type	7.01±2.98			10.380	2	0.010		2.400
Resting	(Intercept)	1.49±1.60	0.933	0.351					
	Distance to road	0.00±0.00	-1.961	0.050	3.846	1	0.50	0.86	2.100
	Bird of prey+nest presence	4.34±1.84	2.362	0.020	5.580	1	0.020		1.333
	Distance to indigenous forest	0.00±0.00	-2.036	0.041	4.143	1	0.041		1.882
Grooming	(Intercept)	-5.00±2.50	-2.039	0.041					
	Mean time	0.28±0.19	1.450	0.150	2.102	1	0.150	0.38	1.024
	Provisioning	1.43±1.12	1.280	0.201	1.640	1	0.201		1.024
Foraging	(Intercept)	-0.07±0.50	-0.163	0.871					
	Bird feeder	0.97±0.64	1.529	0.130	2.340	1	0.130	0.31	1.001
	Raiding	-1.80±0.80	-2.362	0.020	5.580	1	0.020		1.001
Playing	(Intercept)	-0.93±0.34	-2.724	0.010					
	Dog	0.61±0.50	1.230	0.220	1.513	1	0.220	0.13	1.012
	Bird of prey nest	1.90±0.73	2.552	0.011	6.513	1	0.011		1.012

Model based information: df = degrees of freedom; ΔAICc = Delta Akaike Information Criterion; logLik = Log likelihood; wi = Akaike weight; P values significant ≤ 0.05 marked with *; GLMM R^2c = conditional R_2 described by Nakagawa & Shielzeth, (2013) .

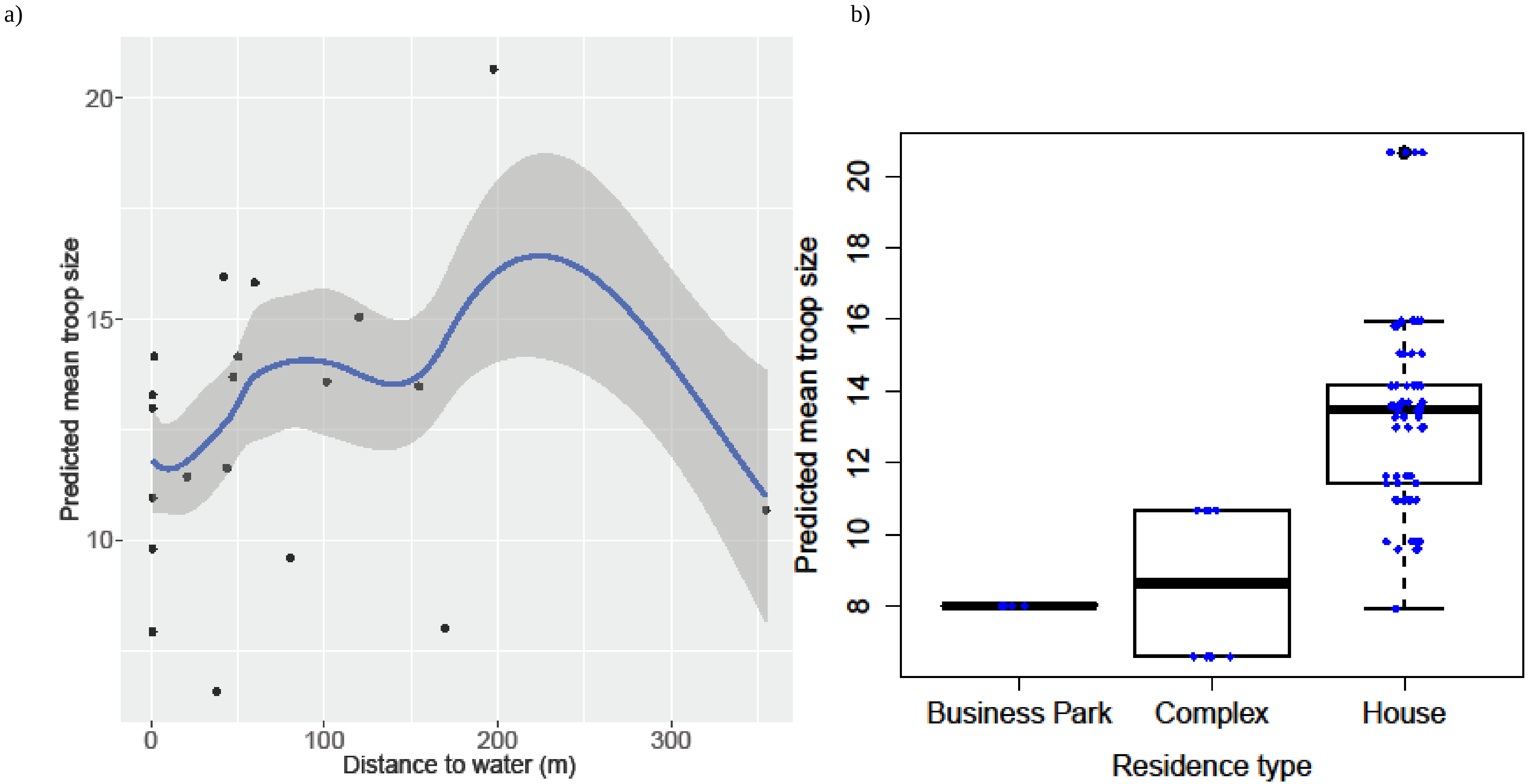

Fig. 4.2. Top-ranked model influencing vervet monkey troop size in urban gardens as a function of distance to water and residence type.

females to each male. The adult and juvenile age classes that were skewed towards females best explained the overall troop sex ratio, in accordance with previous studies showing that females remain in natal groups throughout their life span, with the core of the social group closely related to adult females and their dependent offspring (Isbell, Pruetz, Lewis, & Young, 1999). Provisioning creates food sources that are spatially clumped and monopolisable, so unlike typical non-provisioned populations, in provisioned populations linear dominance hierarchies among females are often found. This provisioning reduces food and mating seasonality, thus females are more monopolisable, leading to troops with significantly higher female ratios to those in the wild, as observed in our study (Pruetz & Isbell, 2000). In addition, differential mortality between males and females is commonly observed in mammals (Clutton-Brock, Harvey, & Rudder, 1977) and has been specifically observed in vervet monkeys, with the “high risk, high gain” hypothesis proving riskier behaviours, including dispersal and competition in and between males, lead to higher mortality rates relative to females (Fairbanks et al., 2004). Following this, vehicle collisions, their pest status, and conflict between residents (and their pets) and vervet monkeys in urban residential areas of KwaZulu-Natal, are known to lead to vervet monkey fatalities (Wimberger, Downs, & Boyes, 2010a; Patterson, Kalle, & Downs, 2017). It is thus likely that male vervet monkeys in our study areas suffer higher mortality linked to anthropogenic pressure, explaining our studies significantly higher female ratios compared to findings for wild troops.

We found support for specific factors influencing the presence of vervet monkeys in urban landscapes. Our results showed that urban vervet monkey troops use residential areas in human-modified habitats not only to forage but to also perform various behaviour functions to maintain cohesion and strengthen social bonds between individuals in a group.

Indigenous forest patches also provide troops with an escape route from threats and conflict and act as a safe refuge in human-modified landscapes, with main roads acting as pathways for troop movement between gardens and forests. Although noise levels and traffic are higher close to the main roads, the relative openness allows troop members to detect potential predators (raptors), thereby decreasing their risk to danger from predation while resting. Moreover, sufficient canopy cover in urban environments is scarce. Therefore, surprisingly, despite the high predation risks involved while resting, vervet monkeys still preferred resting in gardens with high canopy cover despite the presence of raptor nests. Residences with high canopy cover are suitable resting sites as they conceal troop members while resting, thereby minimizing their exposure to predators. Further exploration of the proximity to raptor nests from resting sites and/or the choice of resting sites in terms of the tree species chosen, the height of the trees and the foliage density would provide further clarification for these findings.

The increase in grooming later in the day suggests the appropriate time for socializing and bonding is just before dusk. In addition, food provisioning in gardens leads to less nutritional stress for monkey troops which are able to benefit from easily accessible resources and therefore spend more time on social bonding. We found that grooming was influenced by gardens with a regular supply of provisioned foods, which provide more energy to meet metabolic demands than do wild foods (Jaman & Huffman, 2013) and typically, after consuming the provisioned food, troops frequently rested and engaged in social grooming.

Foraging by vervet monkey troops was influenced by food provisioning, as hypothesised. Our results showed that the presence, and in particular the foraging, of vervet monkeys increased significantly with the increasing frequency of unintentional food provisioning for the monkeys via bird feeders. Food provisioning by people is a causal factor of human-monkey conflict worldwide (Brennan, Else, & Altmann, 1985; Fa & Lind, 1996). Urban-adapted monkeys often develop a taste for human foods, lose their fear of humans, and become proactive (sometimes aggressive) in seeking human food resources (Brennan, Else, & Altmann, 1985; Fa & Lind, 1996). This leads to human-wildlife conflict with the realization of possible risks from bites, theft of human food, or more general health issues such as virus exposures (Else, 1991). Food raiding is integral to the ecology of primates inhabiting areas of human-animal interface and the Cercopithecoids, most notably macaques (Macaca spp.), vervet monkeys, and baboons (Papio spp.) are frequent culprits (Fuentes, 2006; Naughton-Treves, 1998). This is in all likelihood due to their generalized diet and manipulative capabilities (Gautier & Biquand, 1994). Thus, the decrease in foraging in gardens where raiding was present was a possible indication of the conflict that comes with raiding of residences and its effect on vervet monkeys' ability to forage under pressure of possible conflict.

Finally, as hypothesized, we found that playing by vervet monkey troops was influenced by several factors including the presence/absence of a raptor nest(s) and the residency type. The study results also showed increased levels of playing in gardens with dogs and raptor nests suggesting both these factors did not deter vervet monkeys from playing. An explanation may be the presence of dogs deterring other threats for vervet monkeys, such as bird of prey, therefore allowing young troop members more freedom to explore and play within secure properties. Alternatively, non-aggressive dogs may provide enrichment for younger, more inquisitive monkeys.

4.5 Management implications and recommendations

Ours is the first study that adopted a citizen science approach by using local volunteers in collecting basic ecological data on troop size, demography, and behaviour of urban vervet monkeys. We feel that such an approach is applicable to areas and species that are in frequent contact with humans and generates awareness on the scientific processes involved. A participatory approach aids in the monitoring of important urban wildlife and active management of residential ecosystems, two necessary steps in order to come to a consensus on how to mitigate local problems associated with conflict-prone wildlife species. Based on our findings, for those planners prioritising the conservation of indigenous wildlife, including vervet monkeys, we recommend consideration of the protection of existing indigenous flora when building in suburban sites, as well as accommodating additional space for establishing indigenous species in suburban gardens devoid of local flora, particularly in sites with high incidences of raiding.

This research provides justification for further study and development of a more comprehensive spatial dataset in order to provide empirically grounded recommendations for the mitigation of human-vervet conflict and the sustainable management and conservation of vervet monkeys in highly transformed areas of KZN. Finally, the research highlights the value of citizen science and wildlife spatial ecology studies in providing improved mechanisms for identifying priority management and conservation efforts for wildlife at the highly complex human-wildlife interface.

4.6 Acknowledgements

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Appendix 4.1.

The competitive models of troop size, resting, grooming, foraging, and playing of vervet monkey troops in urban gardens of the KwaZulu-Natal Province, South Africa

Response	**Models**	**df**	**logLik**	**AICc**	**ΔAICc**	***wi***
Troop size	**Distance to water + residence type**	**7**	**-241.83**	**499.21**	**0.00**	**0.72**
	Bird feeder + distance to indigenous forest + raiding	7	-243.70	502.95	3.74	0.11
	Bird feeder + distance to indigenous forest + distance to water + residence type	9	-241.30	503.18	3.97	0.10
	Bird feeder + distance to indigenous forest + distance to water + effort days	8	-243.65	505.33	6.13	0.03
	Bird feeder + distance to water + dog+ observer effort + residence type	10	-241.52	506.23	7.02	0.02
	Bird feeder + distance to indigenous forest + distance to water + observer effort + bird of prey nest	9	-243.65	507.87	8.66	0.01
Resting	**Distance to indigenous forest + distance to**	**6**	**-34.07**	**81.29**	**0.00**	**0.71**

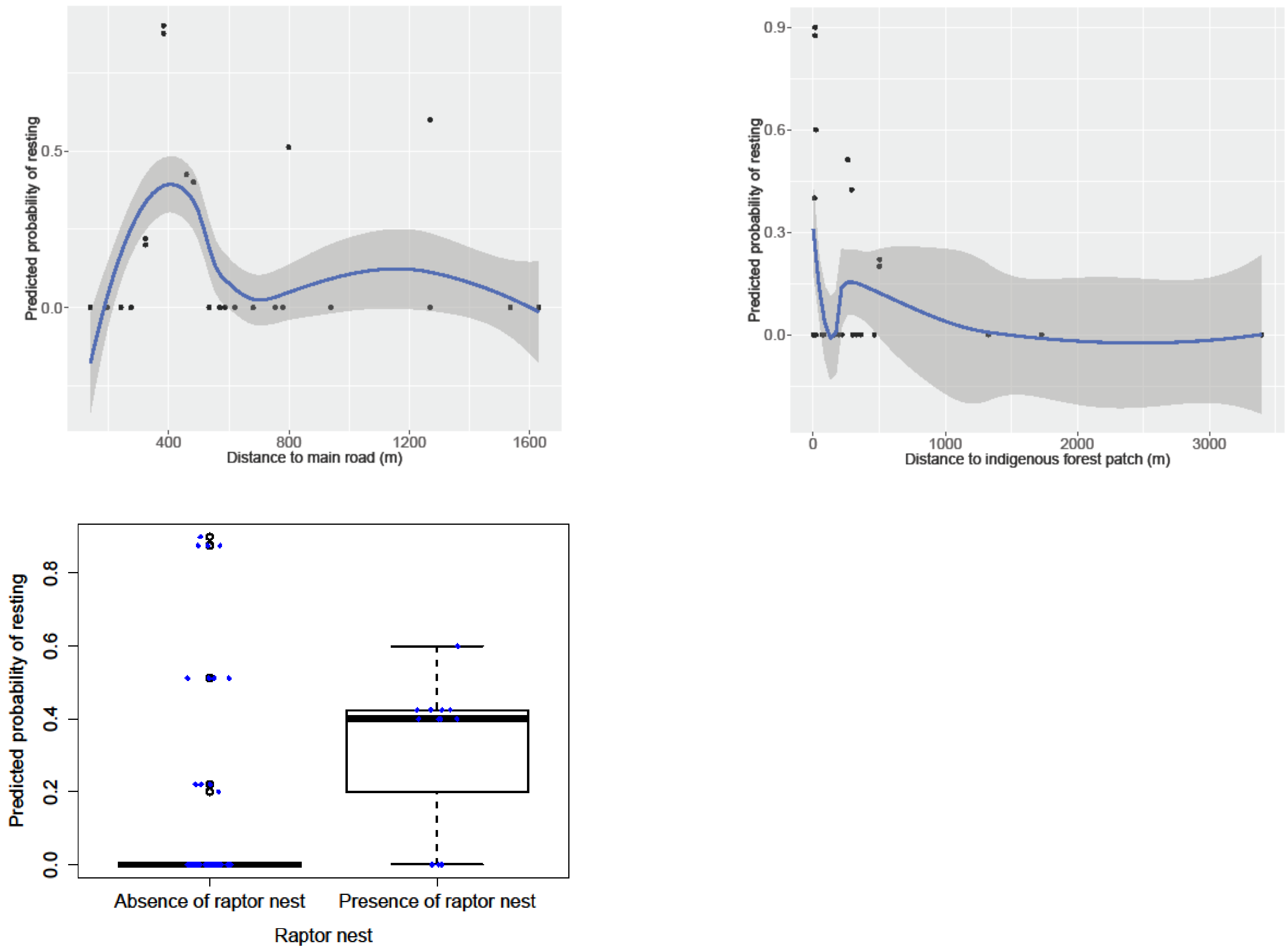
	road + raptor nest					
	Distance to indigenous forest + distance to road + mean time + raptor nest	7	-33.92	83.39	2.10	0.25
	Distance to water + mean time + raptor nest	6	-37.68	88.50	7.21	0.02
	Distance to road + dog	5	-39.38	89.57	8.28	0.01
	Bird feeder + distance to indigenous forest + distance to road + dog + mean time + bird of prey nest + residence type	11	-31.95	89.78	8.49	0.01
	Bird feeder + distance to indigenous forest + distance to road + distance to water + dog + bird of prey nest + residence type	11	-32.28	90.43	9.14	0.01
Grooming	**Mean time + food provisioning**	**5**	**-39.60**	**90.00**	**0.00**	**0.78**
	Canopy cover + distance to road + mean time + food provisioning	7	-38.88	93.32	3.32	0.15
	Canopy cover + distance to road + distance to water + mean time + provisioning	8	-38.76	95.54	5.54	0.05
	Canopy cover + distance to indigenous forest +	9	-38.57	97.71	7.70	0.02

	distance to road + distance to water + mean time + provisioning					
Foraging	**Bird feeder + raiding**	**5**	**-48.50**	**107.82**	**0.00**	**0.63**
	Bird feeder + provisioning + raiding	6	-48.46	110.07	2.25	0.20
	Bird feeder + provisioning + raiding + residence type	8	-46.84	111.72	3.89	0.09
	Distance to road + distance to water + mean time + raiding	7	-48.72	113.01	5.18	0.05
	Bird feeder + provisioning	5	-51.60	114.00	6.18	0.03
Playing	**Dog + raptor nest**	**5**	**-49.49**	**109.80**	**0.00**	**0.57**
	Distance to indigenous forest + dog + raptor nest	6	-49.33	111.81	2.01	0.21
	Distance to indigenous forest + distance to water + dog + food provisioning	7	-48.31	112.17	2.36	0.18
	Bird feeder	4	-53.25	115.04	5.24	0.04

In bold are the best fit models; df = degrees of freedom; ΔAICc, Delta Akaike Information Criterion; logLik = Log likelihood; *wi* = Akaike weight

Appendix 4.2.

Top-ranked model influencing resting by vervet monkey troops in urban gardens as a function of distance to road (m), distance to indigenous forest patch (m) and raptor nest(s).

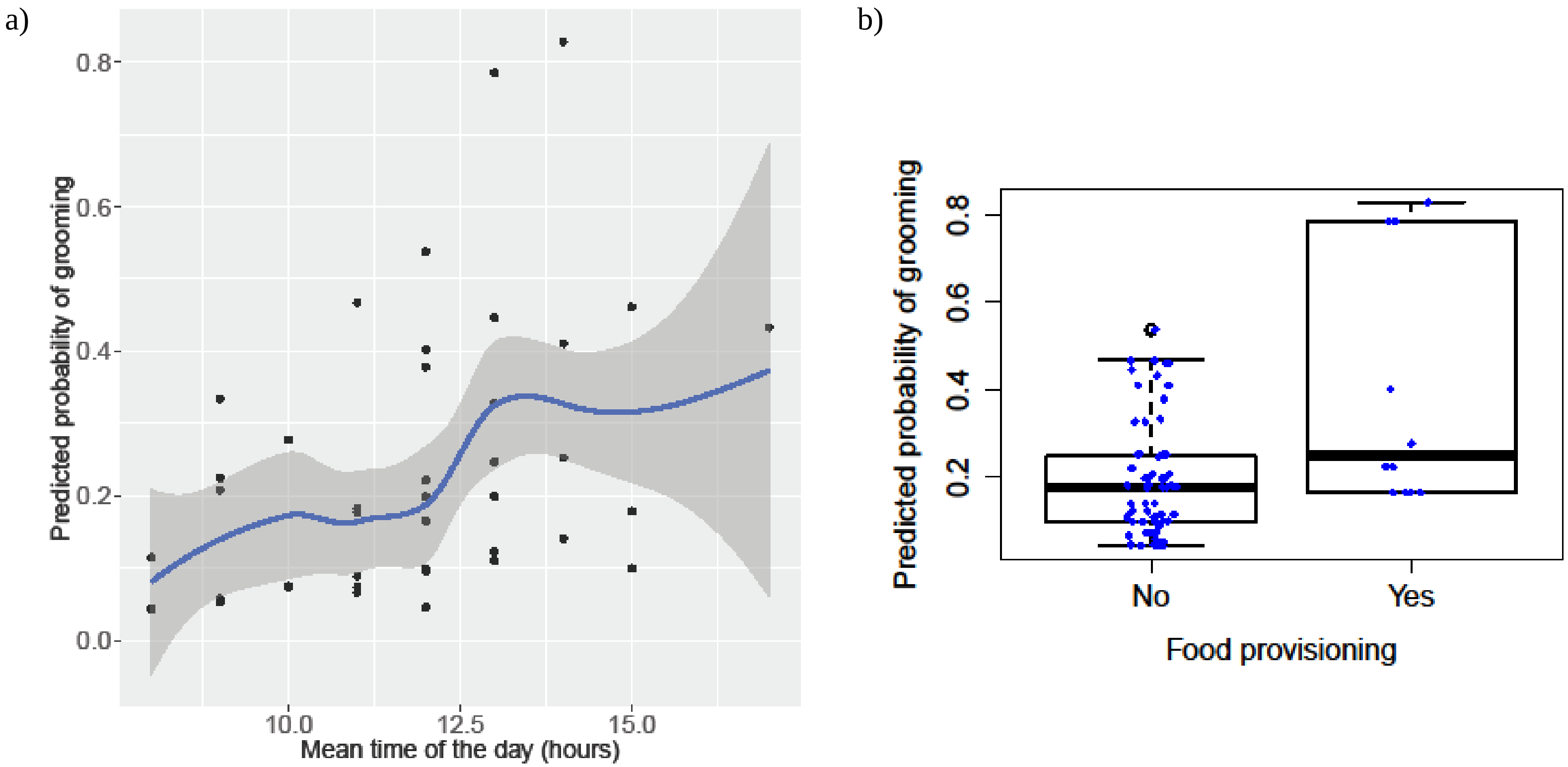

a)

b)

c)

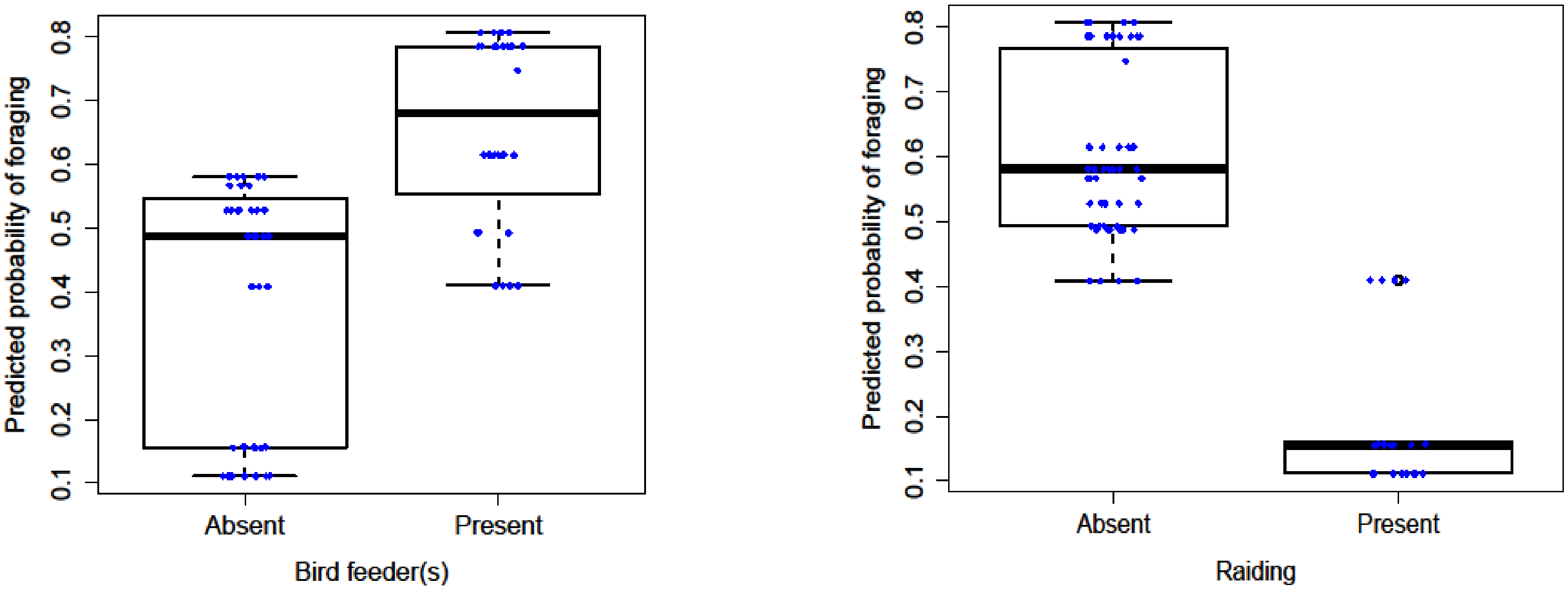
Appendix 4.3.

Top-ranked model influencing grooming by vervet monkey troops in urban gardens as a function of mean time (hours) and food provisioning.



Appendix 4.4.

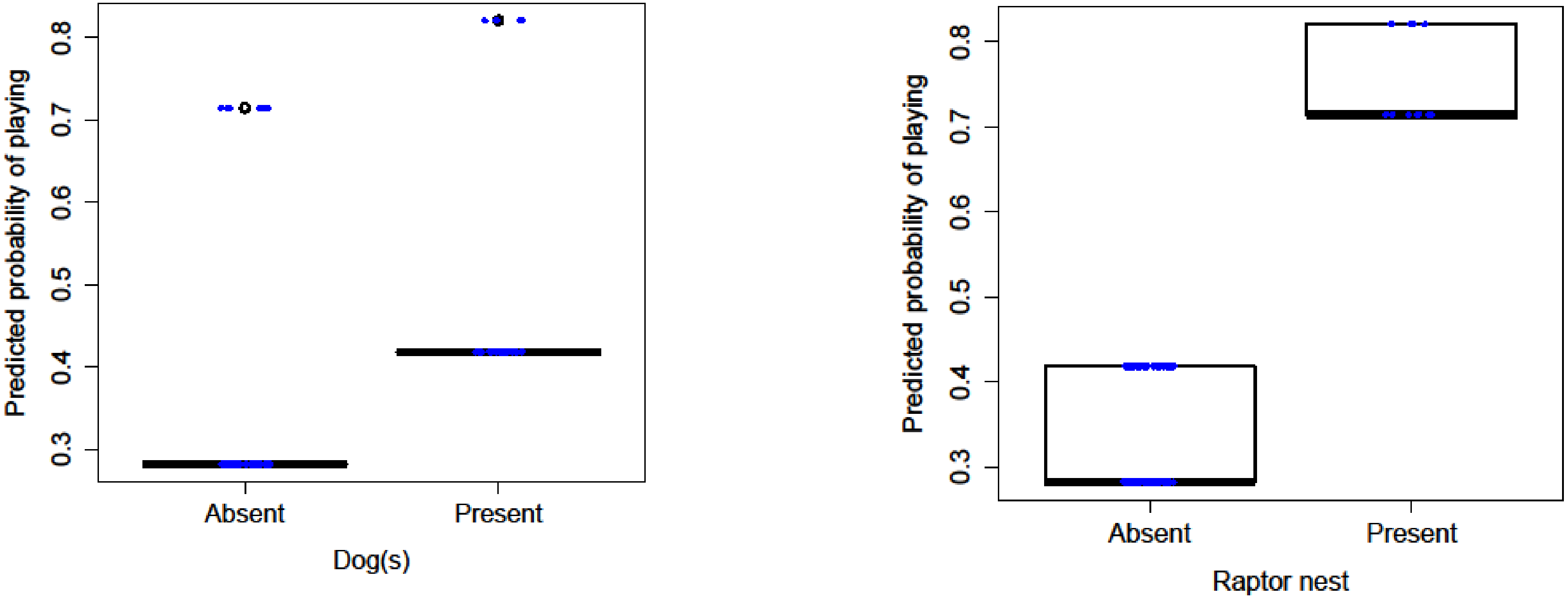
Top-ranked model influencing foraging by vervet monkey troops in urban gardens as a function of bird feeders and raiding.


a)

b)

Appendix 4.5.

Top-ranked model influencing playing by vervet monkey troops in urban gardens as a function of dog(s) and raptor nest(s).


a)

b)

Appendix 4.6.

Seasonal variety in observed diet of urban vervet monkey 649 troops in the KwaZulu-Natal Province, South Africa.

Family	Species	Winter	Spring	Summer	Autumn
Anacardiaceae	*Harpephyllum caffrum* fruit	X			
Anacardiaceae	*Rhus chirindensis* berries			X	
Anacardiaceae	*Schinus terebinthifolius*	X			
Arecaceae	*Raphia australis*				X
Bromeliaceae	*Ananas comosus*	X			
Caricaceae	*Carica papaya*	X			
Euphorbiaceae	*Croton sylvaticus* fruit				X
Fabaceae	*Vachellia karroo* leaf buds	X			
Lauraceae	*Persea americana*	X			
Moraceae	*Ficus natalensis*	X			X
Moraceae	*Ficus sur* leaf	X			
Musaceae	*Musa spp.*	X			
Myrtaceae	*Eugenia malaccensis* fruit			X	
Myrtaceae	*Eugenia uniflora*			X	
Myrtaceae	*Psdium guajava*			X	
Passifloraceae	*Passiflora ligularis* fruit			X	X
Sapindaceae	*Deinbollia oblongifolia* fruit	X			
Strelitziaceae	*Strelitzia nicolai*			X	X
Strelitziaceae	*Strelitzia reginae* flowers				X

CHAPTER 5

Living in the suburbs: Space use by vervet monkeys (*Chlorocebus pygerythrus*) in Simbithi Eco-Estate, South Africa

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Abstract

Urban expansion has replaced many previously agricultural habitats and their landscape structures, with potential benefits to wildlife species that use man-made habitats in rehabilitated ecosystems devoid of large carnivores, and raid human resources. Understanding the habitat use of urban-adapted wildlife aids planners when integrating biodiversity and conflict mitigation into the management of a developing area. Consequently, we examined vervet monkey (*Chlorocebus pygerythrus*) space use using GPS/UHF telemetry data from 10 vervet monkeys across six troops over nine months within a 420 ha eco-estate. We documented a mean home range of 0.99 km^2 (95% MCP) and 1.07 km^2 (95% FK) for females ($n = 6$), 1 km^2 (95% MCP) and 1.50 km^2 (95% FK) for males ($n = 4$) and 0.87 km^2 (95% MCP) and 1.12 km^2 (95% FK) for troops ($n=6$), respectively, indicating that males and larger troops had larger home ranges. These relatively small home ranges included shared territorial boundaries and high home range overlap. Vervet monkey movements indicated higher morning activity levels and habitat selection indicated significantly more use of golf course, urban residential and forest, thicket and woodland areas, and avoidance of wetland, grassland and shrub, and urban built-up areas. Our results suggest that modified-habitat use by vervet monkeys is a consequence of behavioural facilitation to access highly-available food resources, thereby facilitating their persistence in developing ecosystems in South Africa. Therefore, conflict management is dependent on the conservation of sufficient natural habitats and food resources, to minimize their dependence on manmade resources and consequently reduce human-monkey conflict.

Keywords: eco-estate, home range, habitat use, urban-adapted, radio-tracking, vervet monkey

5.1 INTRODUCTION

The way animals use the space available to them has important bearings on their ecology, and in transformed landscapes, daily movements influence social interactions as well as human-wildlife conflicts (Inskip & Zimmerman, 2009; Fehlmann, O'Riain, Kerr-Smith & King, 2017). The first spatial ecology study on primates took place more than eight decades ago (Carpenter, 1934) and introduced ecologists to the extensive variability in ranging patterns that has since been documented across the primate order within and between species (Altman, 1974; Pearce, Carbone, Cowlishaw & Isaac, 2013). Climatic variability in rainfall, temperature and day length are additional influences on ranging patterns (Isbell, 1983; Higham et al., 2009), as direct impactors on primate behaviour (Dunbar 1993; Hill et al., 2003, 2004) and indirectly on natural resources (Bronikowski & Altmann, 1996). Primate spatial ecology is also influenced by troop size (Barton, Whiten, Strum, Byrne & Simpson, 1992; Ganas & Robbins, 2005) and intergroup competition (Isbell, Cheney & Seyfarth, 1991; Wrangham, Gittleman & Chapman, 1993). Troop living may confer the benefit of reduced predation risk to individuals, however intergroup feeding competition can hinder reproduction and compromise survival (Chapman & Chapman, 2000; Ganas & Robbins, 2005). As primate troop sizes increase, so scramble and/or contest competition increase, forcing larger troops to cover larger areas to obtain enough food for all troop members (Wrangham et al., 1993; Chapman, Wrangham & Chapman, 1995). Thus, an increase in troop size should result in a corresponding increase in day range length and home range size (Chapman & Chapman, 2000). This pattern has been widely, but not consistently, found in studies of primates (Gillespie & Chapman, 2001). Troop size correlated positively with home range size and day range length in studies on geladas (*Theropithecus gelada*; Iwamoto & Dunbar, 1983), red colobus (*Procolobus badius*; Gillespie & Chapman, 2001), Thomas's langurs (*Presbytis thomasi*; Steenbeck & van Schaik, 2001), northern muriquis (*Brachyteles arachnoides hypoxanthus*, Dias & Strier, 2003 – home range size only), and mountain gorillas (*Gorilla gorilla beringei*; Watts, 1991, 1998; Ganas & Robbins, 2005). However, there are also cases where primates deviated from the expected. Troop size was shown not to correlate with day range length in studies on patas monkeys (*Erythrocebus patas*; Chism & Rowell, 1988), blue monkeys (*Cercopithecus mitis*; Butynski, 1990), northern muriquis (*Brachyteles arachnoides hypoxanthus*, Dias & Strier, 2003), black and white colobus (*Colobus guereza*; Fashing, 2001), redtail monkeys (*Cercopithecus ascanius*; Struhsaker & Leland, 1988) or kipunji (*Rungwecebus kipunji*; De Luca, Picton Phillipps, Machaga & Davenport, 2009). Furthermore, group size did not correlate with home range size for western chimpanzees (*Pan troglodytes verus*; Lehmann & Boesch, 2003), nor with either day range length nor home range size for black and white colobus (*Colobus guereza*; Fashing, 2001), and several Asian colobine species (Yeager & Kool, 2000).

Typically, our knowledge of primate spatial ecology stems from studies of single troops (Strier, 2017). Studies with large sample sizes of troops (e.g., Bronikowski & Altmann, 1996) or complete populations (e.g., Hamilton, Buskirk & Buskirk, 1976; Iwamoto, 1978; Takasaki, 1981) are rare. However, within species, disjointed populations living under different ecological conditions may differ more from one another in their ranging patterns than they do from closely-related species (Dunbar, 1993; Strier, 2017). The same may be true for troops within the same population that occupy habitats with differential availability, distribution and quality of resources (e.g., Bronikowski & Altmann, 1996). Thus, regardless of the intensity or duration of research, studies with small sample sizes are unable to assess the effects of local habitat differences, or take into account individual differences among troops (Isbell & Young, 1993). Consequently, they may inadequately represent the variation displayed within populations and species (Bronikowski & Altmann, 1996; Strier, 2017). Instead, studies of multiple troops within a population may be more meaningful (Isbell & Young, 1993). This represents such a study.

Previous studies on vervet monkey *Chlorocebus pygerythrus* groups have shown an occupation of relatively small territories, defended aggressively against neighbouring groups (Cheney & Seyfarth, 1981, 1987), however variations in territoriality have been observed frequently enough to substantiate vervet monkeys as exhibiting facultative territoriality (Gartlan & Brain, 1968; Chapman & Fedigan, 1984). This is further substantiated by their occurrence in a variety of habitats ranging from grasslands to swamps, and their adaptability in behaviour and space (Chapman & Fedigan, 1984; Isbell, Cheney & Seyfarth, 1990). One study in Samara Game Reserve, South Africa, showed extensive overlap in the home ranges of neighbouring troops and exploitation of the overlap areas. Minimal intertroop conflict was recorded and no evidence was found of defensive behaviour over food patches or home ranges (Ducheminsky, Henzi & Barrett, 2014).

There is currently little known about the spatial ecology of vervet monkeys. Foord, van Aarde & Ferreira (1994) researched their role as seed dispersers in coastal forests of KwaZulu-Natal (KZN), South Africa and found that habitat utilization differed significantly between the three study troops, with each showing habitat preferences based on preferred resources. Several authors have noted variations and flexibility in the ranging behaviour of vervet monkey troops (Struhsaker, 1967; De Moor & Steffens, 1972), however, their studies refer only to wild troops. Therefore, while vervet monkeys are shown to persist in urban areas (Wolfheim, 1983; Shimada & Shotake, 1997), the absence of urban spatial data has greatly curtailed the efficacy of vervet monkey management efforts in transformed landscapes like KZN. To date, most management decisions have been based on previous practices, public opinion and the suggestions of researchers both with and without relevant experience and knowledge of the local vervet monkey population (Simbithi Environmental Group, 2016 pers. comm.). It is thus likely that until vervet monkey habitat and land-use patterns are incorporated into management plans, vervet monkey management and conservation efforts will remain largely reactionary and serve only to address short term conflicts as they arise.

Our aim was to determine the home ranges and habitat use of adjacent urban vervet monkey troops, based on comparisons between spatial data collected. We predicted that urban areas would have higher densities of vervets (numbers in space) as food is abundant and predators rare. We predicted that daily distances moved would be smaller in urban versus natural areas due to easier access to available food sources and that troops would exhibit preferential use of areas with higher productivity and avoid open, less productive areas. Spatially, primates reliant on widely dispersed, unpredictably available food sources will travel further than those primates who feed on evenly spaced, reliably available foods (Oates 1987, Hoffman and O'Riain 2012). We predicted that urban troops would show increased overlap in spatial use based on inherent constraints imposed on urban living primates, including adapted foraging strategies in areas of limited resources (Barrett, Barrett, Henzi & Brown, 2016). At a finer-scale we predicted that movement and home range sizes would increase in the drier, winter months, with food availability and distribution offering the best explanation for the variation seen in ranging patterns (Clutton-Brock & Harvey, 1977; Riley, 2008; McFarland, Barrett, Boner, Freeman & Henzi, 2014). Temporally, during the drier times of the year, seasonal shifts in the distribution of available food sources may mean further movement during food scarce times compared to food abundant times of the year, as found in previous studies (Isbell & Young, 1993; Buzzard, 2006; McFarland et al., 2014).

5.2 METHODS

5.2.1 Study site

This study was conducted in suburbia in Simbithi Eco-Estate in the suburb of Ballito, north of Durban city centre (420 ha, alt. range: 30-80 m a.s.l., 31°13"11.42' E; 29°30"48.99' S; Fig. 5.1), KZN, South Africa between February and November 2016. Highland sourveld grassland with Themeda triandra and patches of indigenous forest with bush clumps are the dominant natural vegetation (Mucina & Rutherford, 2006). The study area, rehabilitated from what was previously surgarcane plantations and alien vegetation, has many naturally occurring streams and wildlife species within natural habitats inside the estate, including coastal forest, swamp forest, grassland and wetland, with sections extensively converted into residential land (Simbithi Environmental Group, 2016 pers. comm.). The mean annual

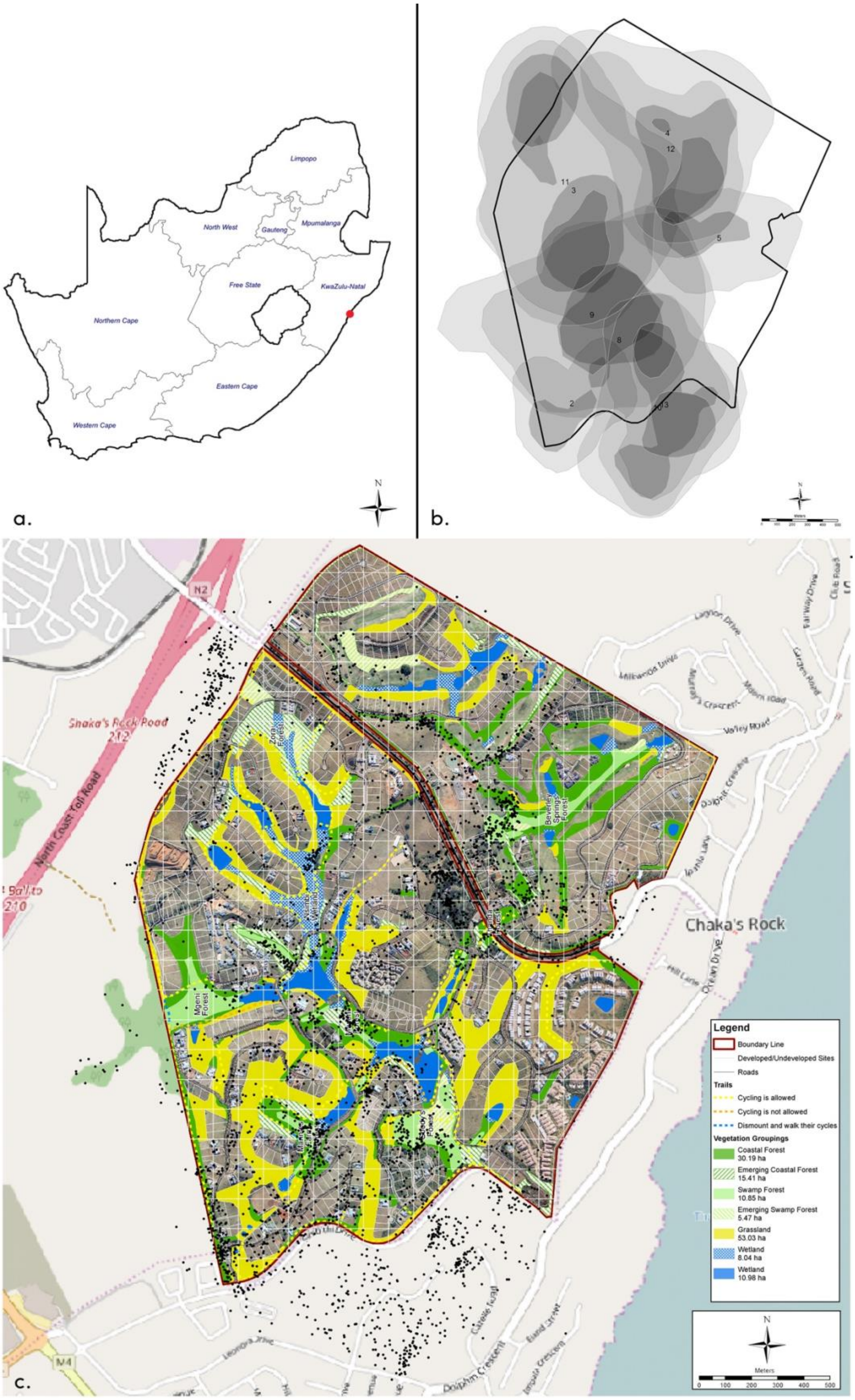


Fig. 5.1. a. Location of the study area (Simbithi Eco-Estate, KwaZulu-Natal, South Africa) showing b. home range estimates for six GPS-collared monkey troops (FK and MCP estimates) and c. the main land use types that characterise the area and the distribution of the six troops GPS fixes (black dots).

temperature ranges from 18.7 to 25.1°C and the average monthly rainfall is 91.6 mm (D. Lilienfeld's Weather Station, Simbithi Eco-Estate, 2016). Six known troops of vervet monkeys share resources within this estate and troop sizes and movements were previously monitored on an ad hoc basis from 2014 – 2016 (Simbithi Environmental Group, 2016 pers. comm.).

5.2.2 Trapping and monitoring procedures

Fourteen telemetry units were fitted to adult and sub-adult vervet monkeys (five sub-adult males and nine adult females) from February-June 2016. Adult females were targeted based on knowledge of the females' influence over troop dynamics (Young, McFarland, Barrett & Henzi, 2017), social security (Josephs, Bonnell, Dostie, Barrett & Henzi, 2016; Henzi et al. 2017) and avoidance of conflict (Arseneau-Robar, Taucher, Schnider, van Schaik & Willems, 2017). Sub-adult males were chosen as they were more likely to remain with or close to the troop than sexually mature males who migrate into and out of troops with the accessibility of adult females (Henzi & Lucas, 1980).

A remote-controlled steel cage trap baited with raw nuts and bananas was used to trap vervet monkeys along known vervet monkey travelling routes within the estate. With the assistance of an experienced veterinarian, captured monkeys were anaesthetized using 0.10 mg/kg ketamine injected intramuscularly, and WW1500AS-TERRESTRIAL GPS/UHF tracking collars (www.wireless-wildlife.org) were fitted. Morphological measurements, fecal, blood and hair samples, and photographs for identification were taken. The approximate age of individuals was determined by morphological characteristics, including weight, sexual development and an assessment of teeth size and wear. No drugs were required for recovery and anaesthetized individuals were closely monitored following release. All capture efforts undertaken followed the procedures outlined by the ethical clearance from the University of KwaZulu-Natal Ethical Committee (Downs 020/15/animal), adhered to the legal requirements of South Africa and adhered to the American Society of Primatologists' Principles for the Ethical Treatment of Primates.

Collars were 60g, and weighed < 2 % of the body mass of individuals. A duty cycle of 1 location (accuracy 5-30m) per 4 h, from 0600 to 1800 daily was employed, resulting in 4 fixes per day. This duty cycle predicted a lifespan of 1356 locations (339 days). The 4 hourly duty cycle was chosen to minimize serial auto-correlation, allowing the use of Minimum Convex Polygon (MCP) and Fixed Kernel (FK) methods (Worton, 1989). Data were downloaded from the collars by a solar power-supported UHF receiver base station positioned at a selected vantage point within the estate and a car-mounted UHF base station moved to vantage points within core areas when signal communication was lost from our static base station. Audio signals verified a successful download on the base stations, and were validated on the website server (www.wireless-wildlife.co.za) 6-24 hours later. Data downloads from telemetry units occurred every 4 weeks and more frequently towards the end of the unit's battery life. These data were stored on an online server. The complete dataset of telemetry locations were verified by a technical supplier and then obtained from the server in February 2017.

5.2.3 Statistical analysis

We followed the most recent recommendations for standardizing animal home range analysis (). Downloaded data were provided with location (WGS 1984), date, time, and velocity. Our data were first assembled onto a time series and NULL locations were counted.

5.2.3.1 Home range estimation

We estimated the home range size of individuals and troops using both MCP and FK methods in the adehabitatHR (Calenge, 2006) package so that methods are comparable with previous studies. Generally, FK estimates provide the best estimate of home range with the advantage of being able to provide estimates when there are limited data points (Worton 1989; Wartmann, Purves & van Schaik, 2010). We calculated home range estimates using 95% MCP, 100% MCP and 95% FK and core areas were defined by the 50% FK isopleth (Campioni et al., 2013; Seaman & Powell, 1996). We followed an ad hoc bandwidth selection procedure which allowed for the reference bandwidth to be reduced until the smallest home range with a contiguous polygon is determined. Consequently, it avoids over-smoothing and unnecessary fragmentation of home ranges (Ramesh, Kalle & Downs, 2016a, b).

Further, we investigated the relationship between habitat variables and use from the telemetry data of the 10 units. Eight of the units covered four troops with data from a collared sub-adult male and adult female, and two troops with data from a collared adult female. For each troop, individual telemetry data were used as surrogates for the movement of the whole troop. The habitat area available to each troop was determined by the area used within the MCP of each collared individual and subsequently subdivided into 100 m x 100 m sub-units (grids) within an area coverage of 10.32 km^2, representing a range of 40 - 106 sampling units for individual coverage and 52-135 sampling units for troop coverage. We superimposed 100 m x 100 m grids over the ecoestate polygon area using GIS software. Earlier studies (Isbell et al., 1998) recorded 82.6 m as the distance travelled by large vervet groups in 30 mins hence we decided to set our grid cell size to 100 m x 100 m as it will allow for the independence of site use every four hours. Hence this grid cell size is the adequate scale for measuring habitat use as the number of GPS fixes in relation to the available habitat in the grid. A total of 625 grid cells were included inside the polygon area of the eco-estate. Grid cells allow for accurate calculation of the proportion of habitat and number of GPS fixes per grid cell as habitat use of vervet troops. We characterized habitat use by calculating the number of GPS locations within a sample grid unit, resulting in vervet use densities. A total of 415 sampling sub-units, encompassing movement of all individuals, resulted from this procedure. We considered independence of neighboring sampling units because the study landscape was highly mosaic in nature due to a focus on habitat management of plants and wildlife within the eco-estate. Prior to this extraction, we made use of the 2014 land cover map for KZN (Ezemvelo KZN Wildlife, 2014) which classified the study area into 6 land use classes, including golf course, grassland and shrub, forest, thicket and woodland, urban, wetland, and cultivation. In each sampling unit, we calculated the available area of land use from the classified 2014 land cover map for KZN (Ezemvelo KZN Wildlife, 2014). We assessed the habitat use based on the number of GPS fixes within each land use class. Statistical analyses were performed in the open-source software R, version 3.0 (R Development Core Team, 2014).

5.2.4 Habitat selection

We used a generalised linear mixed model (GLMM) (Breslow & Clayton, 1993) to investigate the relationship between predictors and habitat use. All the land use classes were chosen as fixed effects, and troop names were included as random effects. The number of fixes per troop were used as a proxy for habitat use. Models were run assuming a Poisson distribution. We ran all possible combinations of the independent variables as predictors of habitat use. Based on the Akaike's Information Criterion (AIC) and Akaike weights (wi), the best-fit models explaining troop habitat use were those with ΔAIC ≤2. The relative importance of each predictor was calculated using the relative ΔAIC weight of predictors, which varied from 0 (no support) to 1 (complete support) relative to the overall models (Burnham & Anderson, 2002).Statistical analyses were performed in the software R, version 3.0 (R Development Core Team, 2014).We conducted all statistical analyses using packages lme4 (Bates, Maechler, Bolker & Walker, 2015), MASS (Venables & Ripley, 2002), effects (Fox, 2003), rJava (Urbanek, 2010), glmulti (Calcagno & de Mazancourt, 2010) and MuMIn (Bartoń, 2013).

5.3 RESULTS

5.3.1 Telemetry deployment and data acquisition

The mean body mass of collared vervet monkeys was 4.6 ± 0.3 kg (n = 14). Age of study animals ranged from approximately 2 - 7 years. For our study, we obtained a maximum of 46–214 days of data from each telemetry unit used for the analysis, which yielded 79–607 GPS fixes. We did not use one unit's data as it came off after 26 days, yielding only 66 locations. After filtering the data, a total of 3,588 GPS fixes were obtained (unit range: 79 - 606 GPS fixes) with a sampling duration range of 40 - 248 days (Table 5.1).

Table 5.1. Details (sex, start date, end date, duration in days, number of GPS fixes and mass) of vervet monkeys (V) collared with GPS/UHF transmitters in Simbithi Eco-Estate, KZN, South Africa.

Individual ID	Sex	Start date	End date	No. of days	No. of GPS fixes	Body mass (kg)
V1	F	15/02/2016	03/09/2016	199	495	2.9
V2	M	01/03/2016	13/08/2016	166	387	4.2
V3	F	15/02/2016	02/06/2016	108	311	3.0
V4	M	15/02/2016	27/07/2016	164	407	6.4
V5	M	15/02/2016	23/07/2016	160	255	6.0
V6	F	15/02/2016	30/06/2016	137	345	3.5
V7	M	29/02/2016	02/10/2016	217	606	4.2
V8	F	23/05/2016	13/08/2016	82	243	3.5
V9	F	26/05/2016	07/11/2016	248	460	4.4
V10	F	06/06/2016	16/07/2016	40	79	4.3

5.3.2 Home range and daily distance moved

The 100% MCP estimates ranged from 55 ha - 327 ha for individuals and from 93 ha - 357 ha for troops (Table 5.2). As expected, the MCP estimates were greater than the 95% FK estimates (Table 5.2). Regardless of estimation methods, home range sizes varied markedly, with one male exhibiting a home range more than double the size of the overall mean. Mean home range sizes of 95% MCP and 95% FK were 99 ha and 107 ha for females (n = 6), 100 ha and 150 ha for males (n = 4) and 87 ha and 112 ha for troops (n = 6), respectively, indicating that males and larger troops had generally larger home ranges (Table 5.2).

Mean 50% FK core areas of female vervet monkeys were smaller than the males and smaller troops (females 25 ha; males 40 ha; Table 5.2), and the 50% FK core areas of smaller troops were smaller than the larger troops (smallest BG: n = 18, 50% FK core area: 12 ha; largest HE: n = 40, 50% FK core area: 32 ha). Troop movements (distance (m) and step length (m)) per 4 h decreased during the afternoon compared with the morning (Table 5.3). During the morning, the maximum distances moved ranged from 487.3 m - 2145.9 m and mean step lengths ranged from 286.7 m - 416 m, while in the afternoon the maximum distances movement ranged from 301.8 m - 1318.8 m and mean step lengths ranged from 144.5 m - 325.2 m (Table 5.3).

5.3.3 Habitat selection

When we modelled the space use of vervet monkeys with the habitat variables, the top models (ΔAIC $\leq$2) identified included urban, golf course and forest, thicket with woodlands, cultivated lands, grassland with shrubs and wetlands, which were substantially associated with vervet monkey resource use as important predictors and provided better fit to the model (Table 5.2; Fig 5.2). Among these six variables, vervet monkey use increased with area availability of the urban and golf course habitat types and is influenced by the forest, thicket with woodland habitat type, while vervet monkey use decreased with area availability of the cultivated, grassland with shrub and wetland habitat types. Vervet monkey space use indicates that vervet monkey use was mostly dependent on urban, golf course and forest, thicket with woodland. Overall our model showed that urban and golf course had high relative importance (Fig 5.2).

5.3.4 Seasonal movement characteristics

All vervet monkeys collared within the Simbithi Eco-Estate urban mosaic stayed in the area for the entire study period, except for V7 and V8 (Goodies Troop), who moved between the estate and urban surrounds. Mean monthly distance moved by individuals differed significantly (Range: 160.6 m – 585.3 m; Appendix 5.1). The overall mean monthly distance was greatest in the month of May (463.6 ± 49.1 m; Appendix 5.1). Individuals covered slightly longer distances in the months of May to July (autumn, mean = 338.8 ± 29.7 m), and shorter distances during the months of March and April (Appendix 5.1). For instance, V7 covered a mean monthly distance of 258.4 m in the month of March and 385.2 m in the month of July (Appendix 5.1). Overall, individuals covered longer distances in autumn (mean = 338.8 ± 29.7 m) and shorter distances in spring (mean = 322.2 ± 26.1 m) (Appendix 5.1).

5.4 DISCUSSION

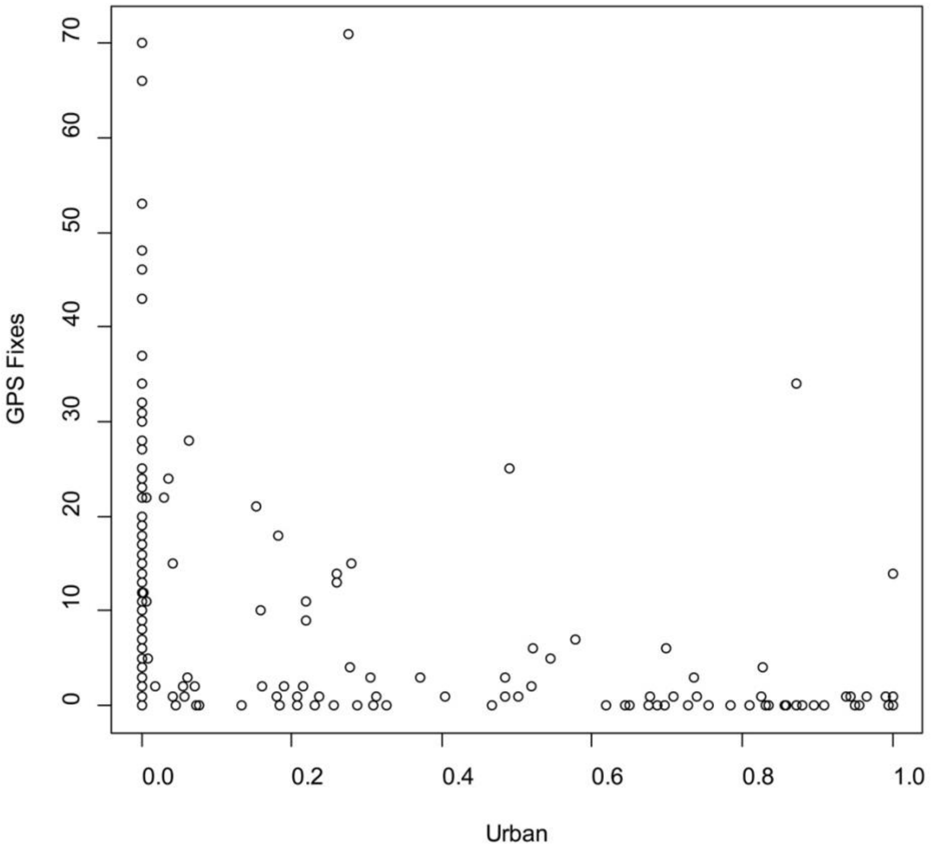
5.4.1 Home range and territory structure

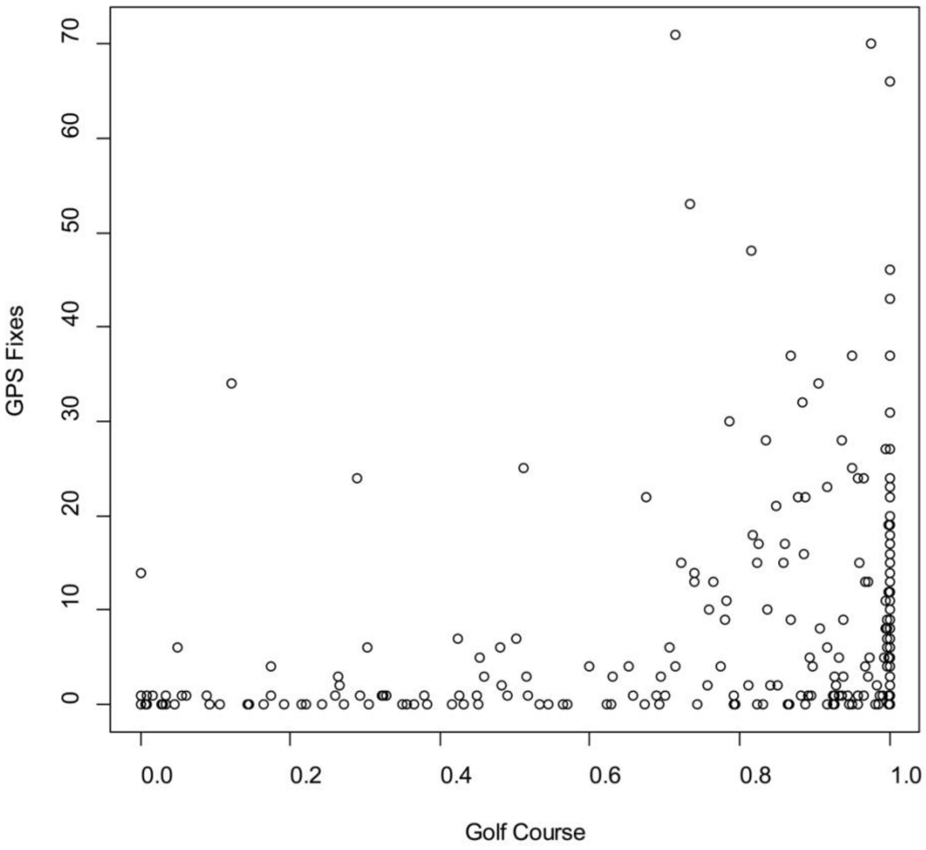
To our knowledge, we present the first results of home range and habitat use of vervet monkeys in an urban environment in South Africa. In order to understand the habitat use by each of the collared vervet monkeys, we first determined the total area used by each individual using the 100% MCP. Although home range sizes can be overestimated by including infrequently used areas (Burgman & Fox, 2003), the MCP method is the simplest home range estimation technique that gives an approximation of the total area used by an animal while making no assumptions regarding the statistical independence of radio-fixes (De Solla, Bonduriansky & Brooks, 1999). Our results showed that the total area covered by each individual and troop varied seasonally (from 0.55 km^2 to 3.27 km^2) with troops travelling significantly longer distances in colder, drier months compared to warmer months, as per previous studies (McFarland et al., 2014).

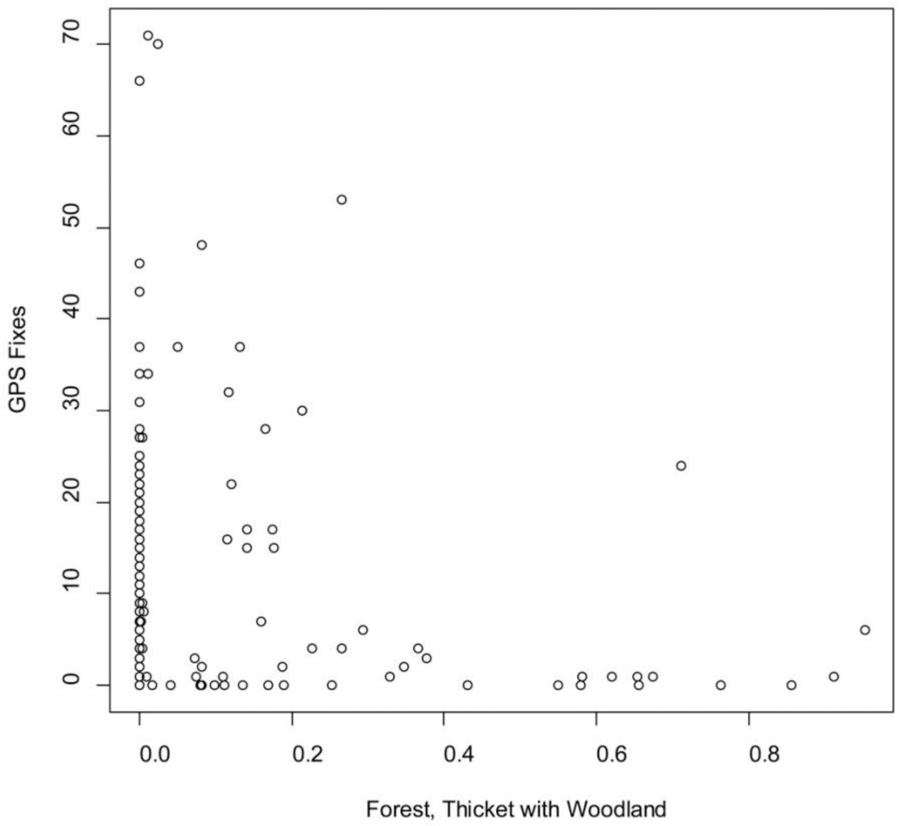
Typically, we found that larger troops had larger home ranges than smaller ones (Table 5.3). In

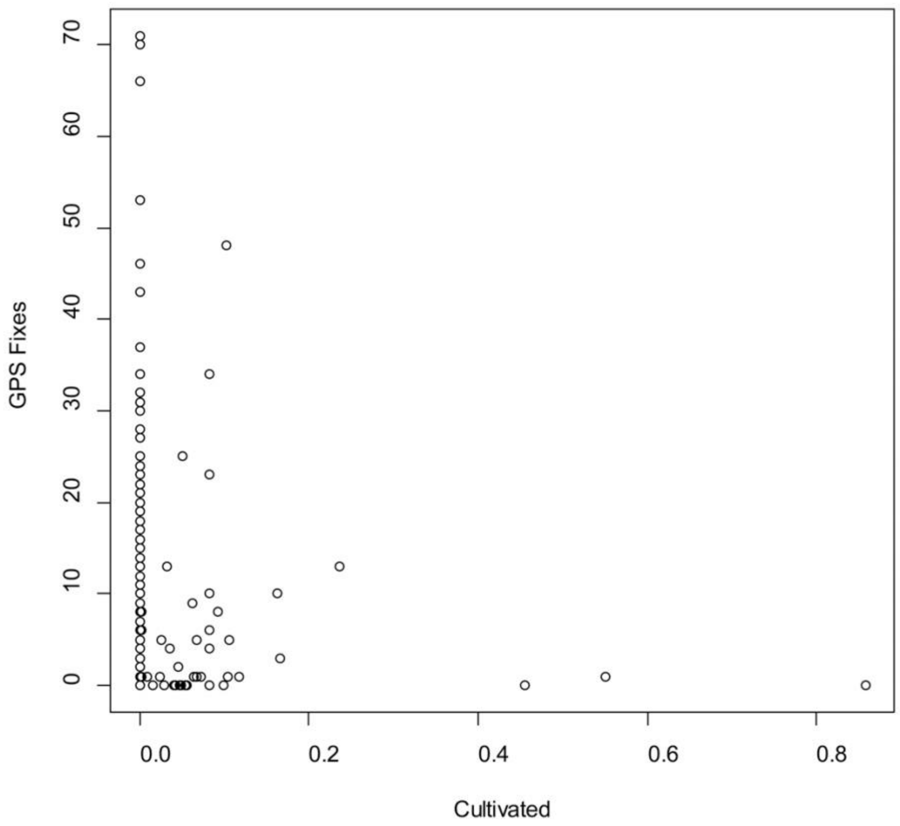
Table 5.2. Generalised linear mixed model showing the candidate models for vervet monkey land use in Simbithi Eco-Estate, KwaZulu-Natal, South Africa.

Selected models	***df***	**logLik**	**AIC**	**deltaAIC**	**Weight**
Urban + golf course + forest, thicket with woodlands	4	-270.90	5415.8	0.00	0.35
Urban + golf course + forest, thicket with woodlands + cultivated lands	5	-270.85	5415.9	0.04	0.34
Urban + golf course + cultivated lands + grassland with shrubs + wetlands	6	-270.91	5416.0	0.20	0.31
Urban + golf course	3	-272.90	5439.9	24.05	0
Urban + forest, thicket with woodlands + cultivated lands + grassland with shrubs + wetlands	6	-271.70	5441.6	25.78	0
Golf course	2	-272.17	5446.4	30.54	0
Urban + forest, thicket, woodlands + grassland with shrubs	4	-273.40	5462.9	47.09	0
Urban + forest, thicket with woodlands	3	-273.58	5469.2	53.40	0
Urban + grassland with shrubs	3	-273.70	5469.4	53.55	0
Urban	2	-274.18	5474.4	58.57	0
Cultivated lands	2	-282.30	5642.5	226.72	0
Wetlands	2	-282.50	5643.0	227.20	0
Grassland with shrubs	2	-282.51	5645.1	229.24	0
Forest, thicket with woodlands	2	-282.20	5650.4	234.60	0


GPS Fixes
0
10
20
30
40
50
60
70
0.0
0.2
0.4
0.6
0.8
1.0
Urban


GPS Fixes
0
10
20
30
40
50
60
70
0.0
0.2
0.4
0.6
0.8
1.0
Golf Course


GPS Fixes
0
10
20
30
40
50
60
70
0.0
0.2
0.4
0.6
0.8
Forest, Thicket with Woodland


GPS Fixes
0
10
20
30
40
50
60
70
0.0
0.2
0.4
0.6
0.8
Cultivated

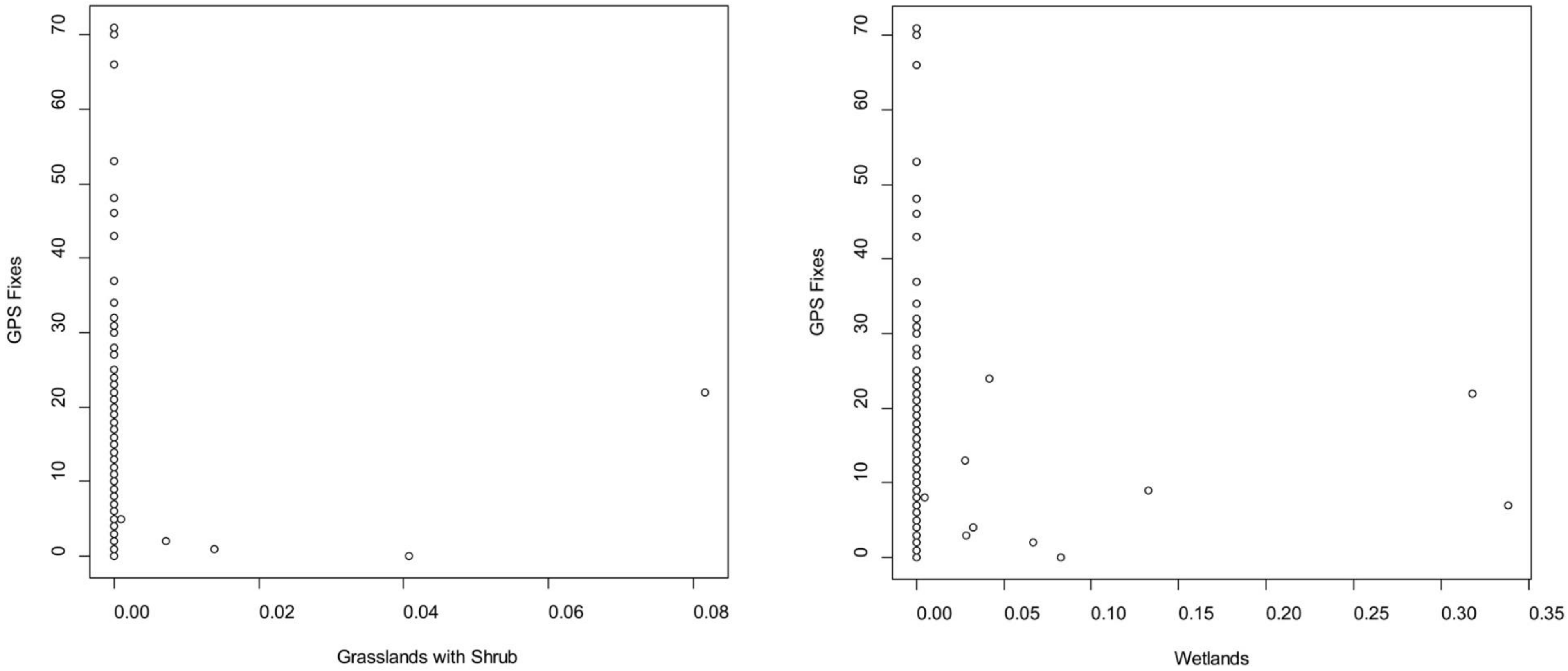


Fig. 5.2. Generalised linear mixed model (±95% confidence intervals) explaining the predicted relationships between vervet monkey use (GPS fixes) and covariates (urban, golf course, forest, thicket with woodland, cultivated lands, grassland with shrub and wetlands) from the best models (≤2ΔAIC).

Table 5.3. Vervet monkey mean (±SE) overall home range sizes estimated using 100% MCP, 195% MCP, 95% FK methods (a) for the ten individuals (V) and the six troops (T) with sufficient GPS fixes and (b) overall mean (±SE) monthly home range size estimated, (b) using the various methods. NR = Not Recorded.

Individual	**Sex**	**100% MCP (km^2)**	**95% MCP (km^2)**	**95% FK (km^2)**	**50% FK (km^2)**	**Troop**	**Troop size**	**100% MCP (km^2)**	**95% MCP (km^2)**	**95% FK (km^2)**	**50% FK (km^2)**
V1	F	2.48	1.36	1.82	0.32	HE	40	3.57	1.48	1.79	0.32
V2	M	3.27	1.21	1.67	0.33						
V3	F	1.46	1.26	1.78	0.49	SA	30	1.5	1.27	1.73	0.45
V4	M	1.21	1.11	1.82	0.44						
V5	M	1.58	0.89	1.4	0.37	IW	NR	1.7	0.92	1.06	0.23
V6	F	0.89	0.73	0.82	0.17						
V7	M	1.1	0.82	1.09	0.33	GO	39	1.1	0.82	1.06	0.32
V8	F	0.55	0.5	0.96	0.25						
V9	F	0.93	0.37	0.49	0.12	BG	18	0.93	0.37	0.49	0.12
V10	F	1.36	0.38	0.57	0.12	FY	31	1.36	0.38	0.57	0.12

Table 5.4. Variation in minimum, maximum and mean daily distances travelled (06h00 – 10h00, 14h00 – 18h00) for six troops of vervet monkeys in the urban-indigenous mosaic of Simbithi Eco-Estate, KwaZulu-Natal, South Africa.

Troop	**Time**	**Min (m)**	**Max (m)**	**Mean (m)**	**Sum (m)**
HE	06h00 – 10h00	10.0	2145.9	371.1	34138.6
	14h00 – 18h00	5.2	301.8	128.2	1667.1
SA	06h00 – 10h00	36.4	846.6	375.4	18019.4
	14h00 – 18h00	27.6	1318.8	325.2	25042.1
IW	06h00 – 10h00	105.7	691.1	374.7	20610.2
	14h00 – 18h00	10.5	745.9	282.8	34789.9
GO	06h00 – 10h00	55.5	842.0	416.0	50341.7
	14h00 – 18h00	13.2	628.6	251.6	5283.5
BG	06h00 – 10h00	51.9	487.3	286.7	15484.4
	14h00 – 18h00	63.7	348.6	176.2	3172.4
FY	06h00 – 10h00	18.9	668.3	320.8	21491.7
	14h00 – 18h00	36.9	319.2	144.5	1589.8

general, larger groups demand larger movement to obtain food resources (Clutton-Brock & Harvey, 1977; Borries, Larney, Lu, Ossi & Koenig, 2008; Pasternak et al., 2013). Smaller troops had smaller home ranges, reflecting highly resourceful areas with adequate food resources and suitable sleeping sites (Teichroeb & Aguado, 2016). The smaller home ranges of vervet monkeys in developed areas is most likely related to the higher density of food resources within smaller areas compared with wild home ranges (ca. 1.76 km^2) in the reserve areas in South Africa (Pasternak et al., 2013). As shown in Isbell et al.'s 1990 study in Amboseli National Park in Kenya, vervet monkeys shifted into the home ranges of neighbouring groups during periods of low abundance of fever trees *Vachellia xanthophloea*. Similarly, this study shows support for the persistence of vervet monkeys in urban landscapes being dependent on their ability to use a variety of habitat matrix; and therefore, less suitable habitats may be used when necessary (Isbell et al., 1990; Barrett et al., 2016). Non-territorial primates have home ranges that overlap with the home ranges of other groups of their species (Strier, 2017). However, they may still aggressively defend particular food sources, such as large fruiting trees, whenever they encounter other primates of their own or other species that compete with them for foods (Georgiev, Klimczuk, Traficonte & Maestripieri, 2013). But, because they require home ranges larger than just their day ranges, they cannot keep intruders out of their home range at all times (Pearce, Carbone, Cowlishaw & Isaac, 2013). Territoriality is not necessarily a fixed attribute of a species and the same behavior, such as aggressive defense of food sources, may be territorial for a group of primates occupying a small home range, but non-territorial in a larger home range (Strier, 2017). Consequently, groups of the same species living under different conditions may be classified differently depending on the degree to which group home ranges overlap with one another (Strier, 2017).

5.4.2 Habitat selection

Our results showed preferential habitat use of the golf course and urban areas within the estate and these two land classes appear to be key predictors for vervet monkey resource use in this urban-indigenous mosaic. The conservation of remnant patches of fragmented natural habitats such as forests with bushland and grassland often surrounded by plantations is essential for long-term persistence of species such as vervet monkeys and other urban-adapted small mammals that are closely associated to natural habitats (Brockerhoff, Jactel, Parrotta, Quine & Sayer, 2008). In our study, the relatively high use of the golf course by vervet monkeys indicates that within this urban landscape these open areas provide suitable protection and foraging opportunities. Therefore, the positive influences of open areas in the space use of vervet monkeys may bridge the gap between sustainable indigenous vegetation management practices and the ecological requirements of generalist feeders. The intensive use of modified habitats by generalist primates has been observed in many studies in agricultural and developed landscapes (Hoffman & O'Riain, 2012; Fehlmann et al., 2017). This has a major influence on wide-ranging species because of their high energy requirements when resources are distributed patchily as a result of habitat fragmentation (Lindstedt, Miller & Buskirk, 1986). Species like vervet monkeys are likely to use developed areas leading to human-monkey conflict particularly when the main land-use includes housing and entertainment (Patterson, Kalle & Downs, 2017). Overall, the eco-estate and its sports and leisure developments influenced the habitat use of vervet monkeys within the home ranges. Vervet monkeys spent more time in modified habitats than the other habitats, thus allowing them to exploit the easily available resources. The highly fragmented patches of forest, thicket and woodland had less of an influence over vervet monkey use.

5.5 RECOMMENDATIONS

Our study demonstrated the habitat use of vervet monkeys in modified habitats in terms of habitat area requirements in highly fragmented landscapes containing a patchy distribution of natural habitat. This shows that eco-estates provide alternative habitats for vervet monkeys. Since the major portions of previous agricultural land have been replaced with living spaces on the north coast of KZN, the management of these conflict-prone generalists is dependent on the conservation of sufficient natural habitats to decrease its dependence on domestic food resources for long-term persistence of the species. Therefore, there are several factors to be considered in land use planning in developed mosaics of KwaZulu-Natal. The viable long-term management options could preserve sufficient natural habitats such as forest, thicket, woodland, grassland and shrub areas to enhance the natural resource availability through ecological restoration. Otherwise, these species are attracted to easy food resources (anthropogenic) in human residential areas leading to retaliatory killing of the species and thus may have an impact on the ecosystem balance, particularly on small mammals.

In South Africa, vervet monkeys are often persecuted by farmers and homeowners (Wimberger & Downs, 2010; Wimberger et al., 2010), however, vervet monkeys could be important ecosystem engineers, which may prove beneficial to conservation concerns (Foord et al., 1994). During our study, some of the non-collared vervet monkeys within the study area and its surrounding landscape were lost to intergroup fighting and vehicle collisions (Patterson, unpublished data). Hence, vervet monkey management must be prioritized within the urbanised landscape by considering behavioural changes of small mammals as structural changes in the habitat will affect foraging and movement behavior of indigenous species living in this landscape. Studies on these human-monkey conflicts are highly valuable in urban landscapes and we suggest that future studies focus on population and fecundity rates of vervet monkeys in the urban landscape with varying degrees of vegetation management/reintroduction under changing land use scenarios to help in the mitigation of human-monkey conflicts.

5.6 ACKNOWLEDGMENTS

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Compliance with ethical standards

All capture efforts undertaken followed the procedures outlined by the ethical clearance from
the University of KwaZulu-Natal.

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Appendix 5.1.

Variation in (a) mean monthly distances covered and (b) mean seasonal distance covered by vervet monkeys in the urban–indigenous mosaic of Simbithi Eco-Estate, KwaZulu-Natal, South Africa. (V = Vervet, NR = No Recordings, Troop = Heron (HE), Savannah (SA), Ironwood (IW), Goodies (GO), Ballito Gate (BG) and Farmyard (FY).

Individual	Sex	Troop	SUMMER		AUTUMN			WINTER			SPRING	
			February (m)	March (m)	April (m)	May (m)	June (m)	July (m)	Aug (m)	Sep (m)	Oct (m)	Nov (m)
V1	Female	HE	585.3	322.3	160.6	336.2	377.5	272.0	NR	NR	NR	NR
V2	Male		524.1	282.2	376.9	400.7	425.1	NR	NR	NR	NR	NR
V3	Female	SA	NR	317.3	335.1	388.9	397.9	438.5	377.3	NR	NR	NR
V4	Male		NR	NR	NR	330.1	321.5	341.3	300.1	NR	NR	NR
V5	Male	IW	276.5	274.6	283.0	378.3	328.8	NR	NR	NR	NR	NR
V6	Female		NR	NR	NR	324.7	241.4	175.7	244.3	235.6	343.9	279.3
V7	Male	GO	178.2	258.4	295.7	334.7	359.6	385.2	388.9	402.7	380.8	NR
V8	Female		NR	NR	NR	NR	288.3	333.7	NR	NR	NR	NR
V9	Female	BG	273.9	251.0	218.1	263.9	254.1	256.7	258.1	336.8	NR	NR
V10	Female	FY	325.3	245.8	247.6	289.1	278.2	287.4	NR	NR	NR	NR

CHAPTER 6
CONCLUSIONS

6.1 Overview

Human-primate conflict is one of the greatest threats to the survival of primates, driven by the division, degradation, conversion and removal of natural habitats for human use (Laurance et al. 2002). However, many generalist primate species exhibiting both dietary and behavioral flexibility, are able to thrive in transformed landscapes (Paterson & Wallis 2005; Strum 2010), as they can adopt new food types, with raiding a common foraging strategy (McKinney 2011). Consequently, many primates come into increasing competition with humans over space and other resources (Lee & Priston 2005). Space use has thus become an important theme in primate studies, with home and day ranges of prime interest for management studies (Arrowwood et al. 2003; Hoffman & O'Riain 2012), especially for smaller, fragmented areas (Robbins & McNeilage 2003). Within the last century, the human population has experienced unrivaled growth and over half of the world's population now live in cities (United Nations, 2014). Despite this, relatively few studies have focused on this urban interface. Primate species known to coexist with humans in urban areas include rhesus macaques *Macaca mulatta* and Hanuman langurs *Semnopithecus* spp. in India (Chauhan & Pirta 2010), Hamadryas baboons *Papio hamadryas* in Saudi Arabia (Biquand et al. 1994), and chacma baboons *P. ursinus* in South Africa (Hoffman & O'Riain 2012; Mormile & Hill 2016). Commensal urban living often presents challenges for both primates and people, and primates utilizing urban spaces are subject to injury or mortality from automobile collisions (Pragatheesh 2011), high voltage power lines (Lokschin et al. 2007), human retaliation (Beamish 2010), and lethal management of individuals or entire populations (Jones-Engel et al. 2011).

Over half of the world's human population currently lives in towns and cities and therefore for a substantial proportion of humanity, interactions with wildlife predominantly take place within an urban, human-dominated system (Charles 2013). In South Africa, the most common primate in rehabilitation centers is the vervet monkey mainly because of their pest status and/or injury in urban areas (Wimberger et al. 2010a,b). Of concern to the welfare of both human and vervet monkey (*Chlorocebus pygerythrus*) populations in KwaZulu-Natal (KZN) are the complaints of human residents to the increasing human-vervet conflicts (HVC) (Wimberger et al. 2010a,b). The continued growth and expansion of the human population and the increasing urbanisation of KZN are likely to exacerbate the levels of HVC. Additionally, these increases may compromise vervet monkey conservation by spatially concentrating the vervet population, leading to increased intraspecies conflicts (Patz et al. 2004).

The vervet monkey is an urban-adapted, generalist feeder and synonymous with human-wildlife conflict in and surrounding developed areas of sub-Saharan Africa (Wimberger et al. 2010a, b). This research has shown that there is a relatively large population of vervet monkeys in an urban landscape in KZN, South Africa (Chapters 3 and 4). The ecology of vervet monkeys in urban areas of KZN was poorly understood prior to this research. Here I contribute new knowledge in three categories;

a) Vervet monkey ecological requirements (Chapters 4 and 5) in an urban landscape.

b) Successful execution of the latest field techniques such as citizen science (Chapter 2 and 4), camera traps (Chapter 3) and GPS telemetry (Chapter 5) revealed new insights into ecology and behavior.

c) Human wildlife conflicts are addressed within this urban landscape of southern KZN (Chapter 2). Human-wildlife conflicts include pet attacks and causes of vervet monkey mortality, thus we propose management guidelines (Chapter 6).

From March 2013 – November 2016, 26 vervet monkey troops have been documented. Six of these troops were tracked by GPS/VHF radio-collars fixed to 13 individuals. These have been in preparation for long term monitoring within Simbithi Eco-Estate. Citizen scientist involvement and additional researcher monitoring will better address questions regarding breeding success, demographics, and recruitment. Finally, I suggest new directions for future research in similar fields.

6. 2 The contribution to ecological knowledge

The vervet monkey in urban areas of KZN was poorly understood prior to this research, which contributes to our hereto-limited knowledge of vervet monkeys, in three aspects. Firstly, the research increases our understanding of public perceptions to urban wildlife, specifically vervet monkey presence in residential properties, and how perceptions may be influenced by vervet monkey behaviours, human-vervet interactions, and vervets potentially negative impacts on urban wildlife (Chapter 2 and 3). Secondly, this research provides novel troop-level and landscape-level data on vervet monkey spatial ecology and factors that may influence their presence in urban areas, therefore adding to the body of knowledge of vervet monkey land use patterns, ranging pattern determinants, intratroop variation and spatial and behavioural adaptability (Chapter 2, 4 and 5). Thirdly, the research provides justification for further study and development of a more comprehensive spatial dataset in order to provide empirically grounded recommendations for the mitigation of human-vervet conflict and the sustainable management and conservation of vervet monkeys in highly transformed areas of KZN (Chapter 2, 4 and 5). Finally, the research highlights the value of citizen science and wildlife spatial ecology studies in providing improved mechanisms for identifying priority management and conservation efforts for wildlife at the highly complex human-wildlife interface (Chapter 2 and 4).

6.3 Execution of advanced field techniques

The artificial nest camera study provides the largest direct-observation data on vervet monkeys in South Africa. These data enable efficient planning of invasive techniques such as camera monitoring and artificial nest experiments.

This is the first study to use GPS telemetry on adult breeding vervet monkeys to investigate home range characteristics and habitat selection (Chapter 5). The sample size of six troops was low and care must be taken when drawing conclusions based on this data, however inferences can be suggested and this study paves the way for a more thorough study using these techniques. We describe a limited population of territories dispersed amongst an urban residential-green space mosaic. A significant effort was invested in capturing sub-adult and adult vervet monkeys in order to fit telemetry devices. These learning experiences have been shared in the field during collaborative communication with experienced veterinarians and field rangers (especially Derrick Lillienfeld, Simbithi Eco-Estate volunteer veterinarian, and Peter Coulon, Simbithi Eco-Estate environmental manager).

Several home range studies are available in the literature, however this study is the first comprehensive study on the urban space use of vervet monkey thus far (Patterson et al. 2017b) (Chapters 4 and 5). The study additionally sought to address public perceptions of human-wildlife conflict and predation pressure on urban wildlife, and we address concerns highlighted through our questionnaire (Chapters 2 and 3).

6.4 Management of ecological and social factors of human-wildlife conflicts

One of the purposes of this research was to provide suggesitons for the active management and mitigation of monkey-human conflicts and conservation concerns. On a citizen science level, a participatory approach aids in the monitoring of important urban wildlife and active management of residential ecosystems, two necessary steps in order to come to a consensus on how to mitigate local problems associated with conflict-prone wildlife species. Based on our findings, for those planners prioritising the conservation of indigenous wildlife, including vervet monkeys, we recommend consideration of the protection of existing indigenous flora when building in suburban sites, as well as accommodating additional space for establishing indigenous species in suburban gardens devoid of local flora, particularly in sites with high incidences of raiding (Chapter 2, 3 and 4).

Our study demonstrated the habitat use of vervet monkeys in modified habitats in terms of habitat area requirements in highly fragmented landscapes containing a patchy distribution of natural habitat (Chapter 5). This shows that eco-estates provide alternative habitats for vervet monkeys. Since the major portions of previous agricultural land have been replaced with living spaces on the north coast of KZN, the management of these conflict-prone generalists is dependent on the conservation of sufficient natural habitats to decrease its dependence on domestic food resources for long-term persistence of the species. Therefore, there are several factors to be considered in land use planning in developed mosaics of KwaZulu-Natal. The viable long-term management options could preserve sufficient natural habitats such as forest, thicket, woodland, grassland and shrub areas to enhance the natural resource availability through ecological restoration. Otherwise, these species are attracted to easy food resources (anthropogenic) in human residential areas leading to retaliatory killing of the species and thus may have an impact on the ecosystem balance, particularly on small mammals.

Over the course of this study perceived health threats were raised. Negative attitudes towards vervet monkeys were highly influenced by the level of negative interactions the survey respondents and/or their pets had experienced (Chapter 2). In many cultures views of monkeys being sacred, however also being pests, overlap, leading to a love/hate relationship, in the midst of which conservation efforts must be managed (Lee and Priston 2005). The results showed that the residents' attitudes towards vervet monkeys were significantly influenced by the kind of interactions they or their pets have had with vervets in the past, particularly with aggressive interactions influencing dislike or hatred towards them. Such conflict presumably leads to a heightened awareness of the implicated species' presence, and may bias residents' reports of their impacts in their area. The respondents' attitudes were a function of the degree of contact with vervet monkeys as pests. Research has shown that contact with monkeys in the absence of home damage or risks tends to promote positive attitudes (King and Lee 1987; Knight 1999), while even minimal experience of raiding or aggression leads to an attribution of blame that may greatly outweigh the extent of damage (Priston 2001).

In South Africa, vervet monkeys are often persecuted by farmers and homeowners (Wimberger & Downs, 2010a; Wimberger et al., 2010b), however, vervet monkeys could be important ecosystem engineers, which may prove beneficial to conservation concerns (Foord et al., 1994). During our study, some of the non-collared vervet monkeys within the study area and its surrounding landscape were lost to intergroup fighting and vehicle collisions (Patterson, unpublished data). Hence, vervet monkey management must be prioritized within the urbanised landscape by considering behavioural changes of small mammals as structural changes in the habitat will affect foraging and movement behavior of indigenous species living in this landscape. Studies on these human-monkey conflicts are highly valuable in urban landscapes and we suggest that future studies focus on population and fecundity rates of vervet monkeys in the urban landscape with varying degrees of vegetation management/reintroduction under changing land use scenarios to help in the mitigation of human-monkey conflicts.

6.5 Limitations in this study and motivations for future research and publications

Quantifying the population size and fecundity rates and qualifying the dietary requirements within the home ranges of urban vervet monkey troops within the Ethekwini, Msunduzi and KwaDukuza municipalities was not within the scope of the current research. Comparative data on home range size differences between urban and rural vervet troops would provide a valuable compliment to this research as well as contribution to urban dietary studies and urban ecology dynamics. In addition to the data presented within this thesis, there are several additional components to the current and proposed future research of the KZN urban vervet monkey population. This comprises two open-ended (1-3) datasets.

1. Knowledge of the fecundity rates will be enhanced with additional years of observation. Twenty six vervet monkey troops were monitored over one-year periods. Surveying for additional years will be increasingly more efficient using the current data (Chapter 4) to focus survey efforts. In addition, surveying troops of differing sizes within differing urban habitat types will enhance our understanding of troop ecology and fission-fusion events.

2. A comprehensive dietary dataset on vervet monkey troops inhabiting contrasting urban habitat types from protected wildlife areas to highly altered developments would enhance our understanding of dietary and behavioural adaptations to restricted availability of resources.

3. Longitudinal studies on the long-term dynamics of urban vervet monkey breeding productivity, land use, and changes in food availability would be of benefit to understanding the temporal dynamics within this environment and which resources need to be conserved. Longitudinal studies are typically limited and difficult to obtain within the timeline of an academic student. Establishing a succession of researchers, volunteer assistants or a community-based monitoring program, such as the monkey monitoring group developed upon in Simbithi Eco-estate during this study would aid in the collection of longitudinal data. Using the urban landscape requirements of the vervet monkey, population evaluations of habitat quality in other African cities may be determined to estimate the potential for vervet monkey occupation and persistence. In addition, comparing vervet monkey life history traits with other monkey species (particularly urban-adapted species such as rhesus macaque *Macaca mulatta* Timmins et al. 2008), and the dynamics of urban areas within the range, may be used to predict urban areas which could provide conservation benefits to those species.

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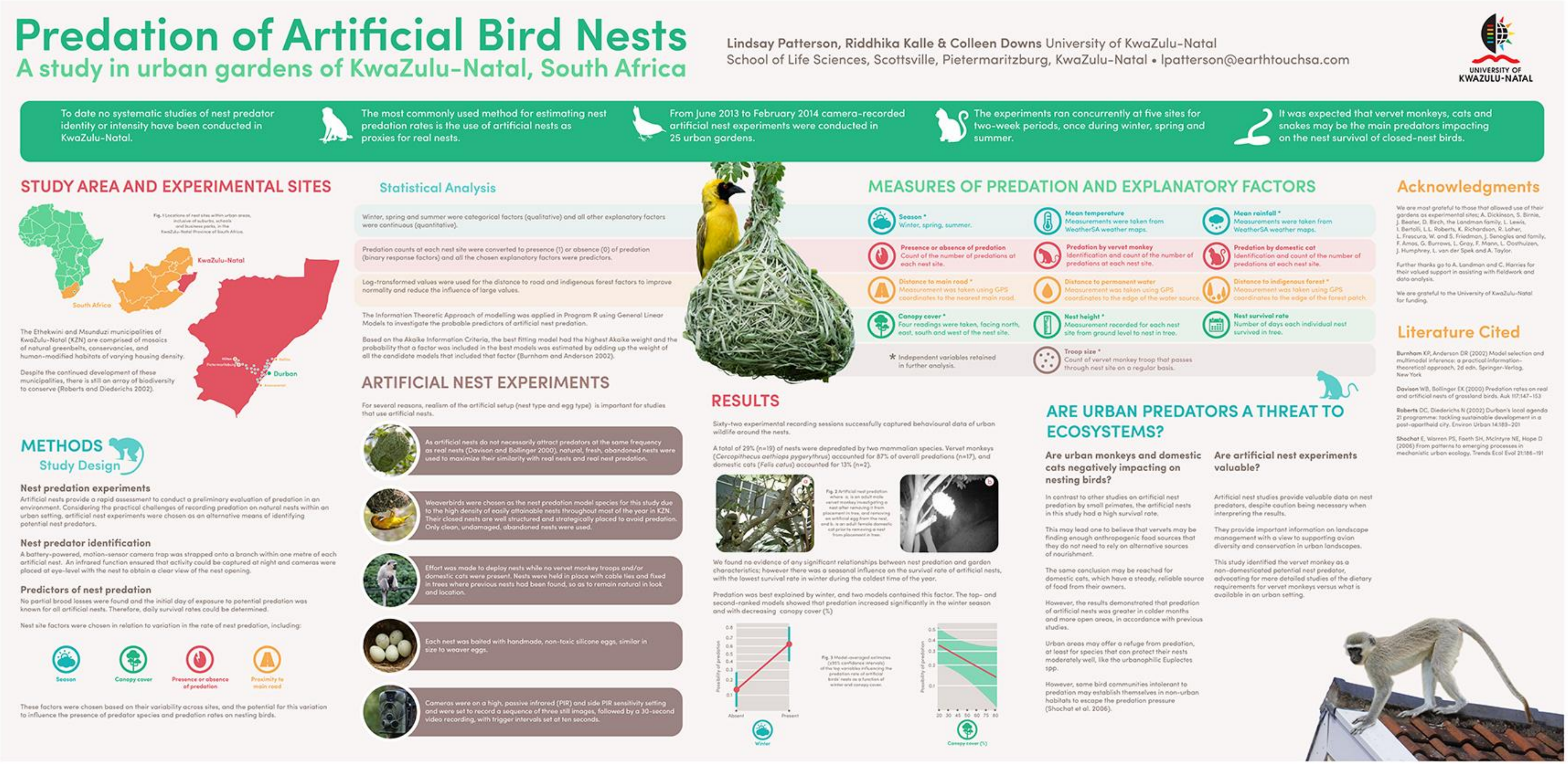
Appendix 6.1.

Information poster presented at PEGG 2016 (Primate Ecology and Genetics Group) and ESA 2016 (Ecological Society of America). PDF available for printing in A3 format.



Predation of Artificial Bird Nests

A study in urban gardens of KwaZulu-Natal, South Africa

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UNIVERSITY OF
KWAZULU-NATAL

To date no systematic studies of nest predator identity or intensity have been conducted in KwaZulu-Natal.

The most commonly used method for estimating nest predation rates is the use of artificial nests as proxies for real nests.

From June 2013 to February 2014 camera-recorded artificial nest experiments were conducted in 25 urban gardens.

The experiments ran concurrently at five sites for two-week periods, once during winter, spring and summer.

It was expected that vervet monkeys, cats and snakes may be the main predators impacting on the nest survival of closed-nest birds.

STUDY AREA AND EXPERIMENTAL SITES

Fig. 1 Locations of nest sites within urban areas, inclusive of suburbs, schools and business parks, in the KwaZulu-Natal Province of South Africa.

The Ethekwini and Msunduzi municipalities of KwaZulu-Natal (KZN) are comprised of mosaics of natural greenbelts, conservancies, and human-modified habitats of varying housing density.

Despite the continued development of these municipalities, there is still an array of biodiversity to conserve (Roberts and Diederichs 2002).

METHODS

Study Design

Nest predation experiments

Artificial nests provide a rapid assessment to conduct a preliminary evaluation of predation in an environment. Considering the practical challenges of recording predation on natural nests within an urban setting, artificial nest experiments were chosen as an alternative means of identifying potential nest predators.

Nest predator identification

A battery-powered, motion-sensor camera trap was strapped onto a branch within one metre of each artificial nest. An infrared function ensured that activity could be captured at night and cameras were placed at eye-level with the nest to obtain a clear view of the nest opening.

Predictors of nest predation

No partial brood losses were found and the initial day of exposure to potential predation was known for all artificial nests. Therefore, daily survival rates could be determined.

Nest site factors were chosen in relation to variation in the rate of nest predation, including:

Season
Canopy cover
Presence or absence of predation
Proximity to main road

These factors were chosen based on their variability across sites, and the potential for this variation to influence the presence of predator species and predation rates on nesting birds.

Statistical Analysis

Winter, spring and summer were categorical factors (qualitative) and all other explanatory factors were continuous (quantitative).

Predation counts at each nest site were converted to presence (1) or absence (0) of predation (binary response factors) and all the chosen explanatory factors were predictors.

Log-transformed values were used for the distance to road and indigenous forest factors to improve normality and reduce the influence of large values.

The Information Theoretic Approach of modelling was applied in Program R using General Linear Models to investigate the probable predictors of artificial nest predation.

Based on the Akaike Information Criteria, the best fitting model had the highest Akaike weight and the probability that a factor was included in the best models was estimated by adding up the weight of all the candidate models that included that factor (Burnham and Anderson 2002).

ARTIFICIAL NEST EXPERIMENTS

For several reasons, realism of the artificial setup (nest type and egg type) is important for studies that use artificial nests.

As artificial nests do not necessarily attract predators at the same frequency as real nests (Davison and Bollinger 2000), natural, fresh, abandoned nests were used to maximize their similarity with real nests and real nest predation.

Weaverbirds were chosen as the nest predation model species for this study due to the high density of easily attainable nests throughout most of the year in KZN. Their closed nests are well structured and strategically placed to avoid predation. Only clean, undamaged, abandoned nests were used.

Effort was made to deploy nests while no vervet monkey troops and/or domestic cats were present. Nests were held in place with cable ties and fixed in trees where previous nests had been found, so as to remain natural in look and location.

Each nest was baited with handmade, non-toxic silicone eggs, similar in size to weaver eggs.

Cameras were on a high, passive infrared (PIR) and side PIR sensitivity setting and were set to record a sequence of three still images, followed by a 30-second video recording, with trigger intervals set at ten seconds.

MEASURES OF PREDATION AND EXPLANATORY FACTORS

Season *
Winter, spring, summer.

Mean temperature
Measurements were taken from WeatherSA weather maps.

Mean rainfall *
Measurements were taken from WeatherSA weather maps.

Presence or absence of predation
Count of the number of predations at each nest site.

Predation by vervet monkey
Identification and count of the number of predations at each nest site.

Predation by domestic cat
Identification and count of the number of predations at each nest site.

Distance to main road *
Measurement was taken using GPS coordinates to the nearest main road.

Distance to permanent water
Measurement was taken using GPS coordinates to the edge of the water source.

Distance to indigenous forest *
Measurement was taken using GPS coordinates to the edge of the forest patch.

Canopy cover *
Four readings were taken, facing north, east, south and west of the nest site.

Nest height *
Measurement recorded for each nest site from ground level to nest in tree.

Nest survival rate
Number of days each individual nest survived in tree.

* Independent variables retained in further analysis.

Troop size *
Count of vervet monkey troop that passes through nest site on a regular basis.

RESULTS

Sixty-two experimental recording sessions successfully captured behavioural data of urban wildlife around the nests.

A total of 29% (n=19) of nests were depredated by two mammalian species. Vervet monkeys (*Cercopithecus aethiops pygerythrus*) accounted for 87% of overall predations (n=17), and domestic cats (*Felis catus*) accounted for 13% (n=2).

Fig. 2 Artificial nest predation where a. is an adult male vervet monkey investigating a nest after removing it from placement in tree, and removing an artificial egg from the nest, and b. is an adult female domestic cat prior to removing a nest from placement in tree.

We found no evidence of any significant relationships between nest predation and garden characteristics; however there was a seasonal influence on the survival rate of artificial nests, with the lowest survival rate in winter during the coldest time of the year.

Predation was best explained by winter, and two models contained this factor. The top- and second-ranked models showed that predation increased significantly in the winter season and with decreasing canopy cover (%)

Fig. 3 Model-averaged estimates (±95% confidence intervals) of the top variables influencing the predation rate of artificial birds' nests as a function of winter and canopy cover.

ARE URBAN PREDATORS A THREAT TO ECOSYSTEMS?

Are urban monkeys and domestic cats negatively impacting on nesting birds?

In contrast to other studies on artificial nest predation by small primates, the artificial nests in this study had a high survival rate.

This may lead one to believe that vervets may be finding enough anthropogenic food sources that they do not need to rely on alternative sources of nourishment.

The same conclusion may be reached for domestic cats, which have a steady, reliable source of food from their owners.

However, the results demonstrated that predation of artificial nests was greater in colder months and more open areas, in accordance with previous studies.

Urban areas may offer a refuge from predation, at least for species that can protect their nests moderately well, like the urbanophilic Euplectes spp.

However, some bird communities intolerant to predation may establish themselves in non-urban habitats to escape the predation pressure (Shochat et al. 2006).

Are artificial nest experiments valuable?

Artificial nest studies provide valuable data on nest predators, despite caution being necessary when interpreting the results.

They provide important information on landscape management with a view to supporting avian diversity and conservation in urban landscapes.

This study identified the vervet monkey as a non-domesticated potential nest predator, advocating for more detailed studies of the dietary requirements for vervet monkeys versus what is available in an urban setting.

Acknowledgments

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Appendix 6.2.

Wildlife survey form for residential engagement in Chapter 3.

Survey number …………….   Please highlight & underline your answer in red.

Wildlife in urban and peri-urban neighbourhoods

Thank you for taking the time to complete this survey. This survey is for information purposes only. Please try to answer all questions to the best of your knowledge and be as accurate as possible, providing reasonably estimated answers when you are uncertain.

This research forms part of a study of wildlife in urban areas currently being undertaken in the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg campus by Lindsay Patterson (MSc candidate) under the supervision of Prof CT Downs.

GENERAL

1. Which suburb do you live in? ____________________________________

2. Do you actively engage in wildlife watching activities?   Yes   No   Sometimes

3. Do you have trees in your garden?   Yes   No

If yes: what percentage of **tree coverage** i~~s there in yo~~ur garden?   > 10%   > 50%   < 50%

4. Of these how many are indigenous and how many are exotic?
50% indigenous   ~~50% e~~xotic   100~~% indig~~enous   ~~100% e~~xotic   Not sure

FORAGING

5. Do you have any fruiting trees in your yard?   Yes   No
If yes: How long do the trees fruit for?   All year   Mar to Aug   Sept to Feb   Not sure

6. Do Indian minahs feed in your garden?   Yes   No   Not sure

If yes: how many individuals do you see **per time** on average?

Under 10   10 – 25   25 - 50

7. Do Hadedas feed in your garden?   Yes   No   Not sure

If yes: how many pairs do you see **per time** on average?

1 pair   2 pairs   3 pairs

8. Do vervet monkeys forage in your garden?   Yes   No   Not sure
If yes: how many individuals do you see per time on average?   __________________________
Less than 10 individuals   10 – 20 individuals   More than 20 individuals   Not sure

9. When do you **mostly** see vervets on your property?   Early morning (06h00 to 10h00)
Midday/Afternoon (10h00 to 14h00)
Afternoon/Evening (14h00 to 18h00)

10. At what time/s of year do vervet monkeys **mostly** come into your property?
Sept to Nov   Dec to Feb   March to May   June to Aug   Not sure

11. How often do vervet monkeys enter your property?
Daily Weekly Occasionally Not sure
12. How long do vervet monkeys stay on your property on average?
A few minutes Half an hour An hour Over an hour Not sure
13. Do you have a dog/s? Yes No
If yes: what is your dog's response to the presence of Indian minahs and Hadedas?

Bark Chase Ignore Watch

If yes: have you ever seen Hadedas stealing food from your dog's bowl? Yes No

If yes: what is your dog's response to the presence of vervet monkeys?

Bark Chase Ignore Watch

14. Have you ever seen vervets stealing food from your house? Yes No
If yes: how often on average? Daily Weekly Occasionally Once
15. Do you have birds' nesting in your garden? Yes No

If yes: what species? Weavers Hadedas Indian Minahs Parakeets Other

If yes: for how many years have you noticed birds nesting in your garden?

Less than one year 1 – 5 years 5 – 10 years More than 10 years Not sure

If yes: At what time/s of year have you noticed nesting?

Sept to Nov Dec to Feb Mar to May June to Aug

16. In which type of tree have you seen nests? Indigenous Exotic Both Not sure

name of tree/s (if known) ____

17. Have you ever seen vervets stealing eggs from birds' nests? Yes No
If yes: how many times on average? Once Under 5 times More than 5 times

18. Have you seen vervet monkeys eating from rubbish bins/bags in your garden? Yes No

If yes: how often do you see this behaviour? Daily Weekly Occasionally Once

when have you **mostly** seen this behaviour?

Sept to Nov Dec to Feb Mar to May June to Aug Not sure

BEHAVIOUR
19. Do you ever hear Hadeda calls from your property?
If yes: when do you **mostly** hear Hadeda calls? Early morning (6h00 to 10h00)
Midday/Afternoon (10h00 to 14h00)
Afternoon/Evening (14h00 to 18h00)
20. Do you ever hear vervet monkey calls from your property?
If yes: When do you **mostly** hear vervets calls? Early morning (6h00 to 10h00)
Midday/Afternoon (10h00 to 14h00)
Afternoon/Evening (14h00 to 18h00)

21. Have you ever seen other animals interacting with vervets in your garden? Yes No

If yes: which animals? Hadedas Indian minahs Cats Genets Parakeets
Other: ____

SLEEPING

22. Have there been or are there vervets **sleeping** in your garden? Yes No

If yes: how many individuals on average?___________________________

Less than 10 individuals 10 – 20 individuals More than 20 individuals

23. For how many years have you noticed vervet monkeys sleeping in your garden?

Less than one year 1 – 5 years 5 – 10 years More than 10 years Not sure

at what time/s of year? Sept to Nov Dec to Feb Mar to May June to Aug Not sure

in which tree/s? Indigenous Exotic Both indigenous & exotic Not sure

name of tree/s (if known) ____

---

24. How many infant vervets do you see **per year on average**?

Under 5 5 – 10 10 – 15 Over 15

ATTITUDE

25. How do you feel about Indian minahs?

Hate Dislike Neutral Like Love

Briefly explain why you feel this way about Indian Minahs ______________________________
____
____

26. How do you feel about Hadedahs?

Hate Dislike Neutral Like Love

Briefly explain why you feel this way about Hadedas
____
____

27. How do you feel about vervets?

Hate Dislike Neutral Like Love

Briefly explain why you feel this way about vervets ______________________________
____
____

28. Do you think Indian minahs and Hadedas carry diseases?

If yes: Where did you hear about it? ______________________________________

29. Do you think vervets carry diseases? Yes No

If yes: Where did you hear about it? ____

CONTACT DETAILS (optional)
If you have hadedas and/or vervet monkeys foraging or sleeping in your garden and would like to further assist in this study, please provide your contact details
Name ____
Address ____
Telephone ____
E-mail address ____

Further comments:
____
____
____
____

Thank you, your participation is greatly appreciated.

Contact:
Prof. C.T. Downs or Lindsay Patterson
Email: downs@ukzn.ac.za or lpatterson@earthtouchsa.com
Telephone: (033) 260 5127/ 04, or (031) 582 0800/69 with any questions or comments.

Appendix 6.3.

Recording sheet for vervet monkey observational work (Chapter 4).

Urban Vervet Monkey study, University of KwaZulu-Natal

Observer’s name & surname:……………………………………..Tel/cell no:…………………
Suburb, street name & house number: ………………………………………………………
GPS coordinates (if known):……………………………………………………………
e-mail:………………………………………

Your assistance is gratefully appreciated. Please fax or email data sheet monthly to Lindsay Patterson (MSc Candidate) (email:lpatterson@earthtouchsa.com) or Prof CT Downs (Supervisor), School of Life Sciences, University of KwaZulu-Natal, P/Bag X01, Scottsville, Pietermaritzburg, 3209. Telephone: 033 260 5127/04, Cell: 0829202026, Fax: 033 260 5105; Email: downs@ukzn.ac.za. Please contact us for further information if required.

Date	Time	Number of vervets in troop passing through garden	Number of adult females in troop	Number of juveniles in troop	Notes or comments (e.g. foraging, fighting, mating, etc)