Assessing spatial and temporal variation of baboon demographics in Baviaanskloof, Eastern Cape, South Africa

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DECLARATION

I, Elihle Mankuntsu, hereby declare that this thesis entitled "Assessing spatial and temporal variation of baboon demographics in Baviaanskloof, Eastern Cape, South Africa" is my original work carried out in the Department of Zoology and Entomology, Rhodes University under the supervision of Prof. Travis W. Perry, Dr Nokubonga Mgqatsa, and Ms. Maya Beukes. All components of this thesis have not been submitted for any degree or examination at any other university or tertiary institution.

DEDICATION

I dedicate this thesis to me. I thank God for honouring and respecting his word when he said, "I will never leave you nor forsake you not in any circumstance" Hebrews 13: 5 and when he said, "I will guide you along the best pathway for your life. I will advise you and watch over you" Psalm 32:8. He came through for me many times and he fulfilled his promise.

Chapter One: Baboons in a changing landscape: Ecological implications of habitat conversion

Impacts of habitat conversion on wildlife ecology

The rapid and widespread conversion of natural habitats to alternative land uses, such as farming, has the potential to influence protected areas and their associated wildlife. For instance, agricultural activities expose wild animals to cultivated foods (Gillingham & Lee 2003; Paterson et al. 2005; Woodroffe et al. 2005), and this causes them to adjust their feeding ecology to exploit cultivated landscapes (Slater et al. 2018). Consequently, wild animals may expand their home ranges into neighbouring privately owned lands to meet their dietary needs, leading to human-wildlife conflicts (e.g. Large felid species (*Puma Concolor*), Olive baboon (*Papio anubis*), etc) (Strum 2010; Forrest et al. 2012; Ripple et al. 2014). However, the extent to which these alternate land-use changes influence wild animals' behaviour in different areas is not well understood, and this poses limitations on the ability to effectively manage wildlife across land-use types and different landscape types, including inside and outside of protected areas (Tscharntke et al. 2012; Lambin & Meyfroidt 2011).

Crop raiding is one of the leading sources of conflict between wildlife and humans worldwide (Woodroffe et al. 2005). It threatens biodiversity conservation efforts by fostering negative perceptions of wildlife and can undermine the economic stability of rural communities (Naughton-Treves & Treves 2005). Negative attitudes, especially towards large species such as elephants and large primates, can be intensified by concerns about the potential threat these animals pose to human safety (Webber et al. 2011; Fehlmann et al. 2017b). As a result, crop-raiding animals, including endangered and legally protected taxa, are likely to face harassment, physical injury, or even death when confronted by humans (Hill et al. 2002; Sitati et al. 2003; Hockings et al. 2010). For example, baboons are well known for being frequent raiders, especially males (Strum 2010; Chiyo et al. 2012), as such, they are treated as pests in some places and this behaviour puts both human and baboon life at risk (Drewe et al. 2012; Beamish & O'Riain 2014; Webber & Hill 2014). Baboons are a highly adaptable species, inhabiting diverse environments (Stuart & Stuart 2015; Fischer et al. 2019). Although they are common, the knowledge about their biological and behavioural traits remains limited in some places, such as Baviaanskloof, which limits our ability to comprehend their ecological roles and social structures in this area. Therefore, investing more effort into their adaptation mechanisms and the challenges they face in a changing environment like the Baviaanskloof area before any conservation effort is crucial, and it could also help us gain vital insights into their biology.

Lastly, understanding the relationship between different landscape types, land use, and baboon behaviour is essential for determining sustainable land-use practices and identifying the landscape types that baboons utilise most.

Taxonomy and distribution

Old-world monkeys belong to the Family of Cercopithecidae, which consists of about 22 genera and ~132 species (Gray 1821; Lawrence & Cords 2012; Stuart & Stuart 2015). One of these genera is *Papio*, which consists of six species: the chacma baboon (*Papio ursinus*), olive baboon (*Papio anubis*), yellow baboon (*Papio cynocephalus*), guinea baboon (*Papio papio*), kinda baboon (*Papio kindae*), and hamadryas baboon (*Papio hamadryas*) (Jolly 1993; Groves 2001; Fischer et al. 2019). The *Papio* species are found in different parts of northern and southern Africa (Phillips-Conroy & Jolly 1986; Bergman et al. 2008; Walker et al. 2017). This study focuses on the chacma baboon (*Papio ursinus*), which is commonly known as the Cape baboon or savanna baboon (Stuart & Stuart 2015). They are widely distributed across southern Africa (Namibia, Lesotho, southwestern Angola, Zambia, Zimbabwe, Botswana, Eswatini, Mozambique, and South Africa) (Stuart & Stuart 2015; Sithaldeen 2019).

Physical description and dietary adaptations

Chacma baboons are sexually dimorphic (Dechow 1983; Stuart & Stuart 2015); adult males are larger (30 – 40 kg), with a more pronounced dog-like muzzle, sharp long canines for feeding and defence, and dark-brown coat with a mane (Dechow 1983; Bulger & Hamilton 1987; Johnson 2003; Stuart & Stuart 2015). Adult females are smaller (15 – 20 kg), with brown coats and ischial callosities, which turn scarlet during the oestrus period to notify the males about their readiness to mate (Dechow 1983; Bulger & Hamilton 1987; Johnson 2003; Stuart & Stuart 2015). Juveniles have greyish-brown coats, and they are independent of their parents, while infants are born with black coats and pink tiny faces, fully dependent on their parents (Stuart & Stuart 2015). Chacma baboons are opportunistic omnivorous feeders, eating both plant and animal matter, including small antelopes, roots, barks, leaves, ants, seeds, corms, grass, bulbs, fruits, and invertebrates (Smithers 1983; Hill et al. 2000; Stuart & Stuart 2015; King 2016; Alberts & Gaillard 2018). Their flexibility in diet allows them to feed on human food sources by raiding cultivated crops, trash cans, and homes (Falls 1993; Hill 2000; Fehlmann et al. 2017b).

Baboon society

Baboons live in troops that are usually made up of 15 – 200 or more individuals (Stuart & Stuart 2015; Spencer 2020). In a troop, there is usually a hierarchy and matrilines, with dominant males maintaining status through displays and aggression (Cheney 1977; Bergman et al. 2003). Dominant females have the advantage of first access to nutrient-rich food and water, priority in mating, preferred sleeping sites, and constant protection from the dominant male, especially when they are accompanied by their infants (Bergman et al. 2003; Stuart & Stuart 2015; Alberts & Gaillard 2018). Subsequently, their offspring inherit their mothers' rank (Cheney 1977; Bergman et al. 2003). Sub-adult males move out of their natal group when they reach sexual maturity (around 5 – 8 years) to form a bachelor group or challenge neighbouring troops to take over (Cheney & Seyfarth 2007). After gaining dominance as an alpha male in a particular troop, they kill the infants (infanticide) and force the females to mate with them (Cheney & Seyfarth 2007; Stuart & Stuart 2015; Spencer 2020). Sub-adult females remain with their natal troop until they reach sexual maturity and take dominance in matriline, passed by their mothers, lasting for generations (Cheney 1977). They form strong bonds and relationships with other non-dominant females and males in the troop (Cheney 1977; Cheney & Seyfarth 2007). Juveniles and infants spend their time playing (chasing, climbing, and biting), this prepares them for the future when they are old enough so they can take care of their young and protect themselves (Owens 1975). Chacma baboons have a longevity of 20 to 40 years in the wild and up to 45 years in captivity (Stuart & Stuart 2015).

Reproduction

Chacma baboons are non-seasonal breeders (Stuart & Stuart 2015). Females exhibit polyoestrous cycles and visual cues of fertility, and both males and females directly rear offspring (Altmann et al. 1988). An adult male may mate with multiple females in a troop, and an adult female may mate with multiple males (Stuart & Stuart 2015). The female will give birth to an infant weighing about 600 g to 1.5 kg (Stuart & Stuart 2015), infants are born altricial and dependent on their mothers` instinct and the ability to protect and feed them for the first four to six months (Alberts & Gaillard 2018). In the first few weeks, the infant clings to its mother, but after three months, it starts riding on her back, having gained enough confidence by then (Stuart & Stuart 2015). Infants become weaned when they reach 10-15 months old, by this time they are independent of their mothers, and they become juveniles, playing and learning from their fathers (King 2016; Onyango 2013). They later become sub-adults and males leave their troop while females remain with the troop for the rest of their lives (Cheney & Seyfarth 2007; Spencer 2020).

Conservation and management

The conversion of natural habitats to human-modified habitats has affected many animals and caused unbearable interactions, such as human wildlife conflicts (Biquand et al. 1994; Creachbaum et al. 1998; Seiler 2005; Gurung et al. 2008). Chacma baboons are one of the species that are affected by these transformations and are known as successful and frequent raiders, which causes them to be regarded as pests/nuisances (Webber & Hill 2014). They mostly raid agricultural areas, homes, shops, people carrying food, and garbage, which causes conflict, and in some areas raiding is severe and requires management strategies to address the issue (van Doorn et al. 2010; Barnagaud et al. 2011; Kaplan et al. 2011; Hoffman & O'Riain 2012; Sih 2013). Multiple methods have been employed to combat baboon-human conflict, and these methods include electric fences, trash bin proofing, and herders (Cape Nature 2012). To minimise their drastically growing population, culling, translocation (Dickman 2010), and reproduction control (male vasectomy and hormonal control of female fertility) have been employed (Biquand et al. 1994). Even though humans could kill baboons during human-baboon conflicts, their overall population numbers remain high and unknown in some places.

Baviaanskloof is one of the places in southern Africa that experiences human-baboon conflict due to the transformation of natural habitats to human-modified environments (Urquhart 1990), which leads to raiding. The current population of baboons in this region remains unknown, presenting challenges for management efforts. Additionally, no studies have been conducted on baboons in this area, making it an important location to study their ecology and the potential influence of environmental changes on their behaviour. Baboons are one of the animal species that play an important role in maintaining ecosystem structure and functioning (Tew et al. 2018). For example, they play an important role in seed dispersal and soil aeration (Tew et al. 2018). Although categorised as a species of least concern by both the IUCN and the South African Mammal Red List (Sithaldeen 2019; Hoffman & Hilton-Taylor 2008), the extent to which baboons utilise the landscapes and how they are affected by changes in land use and season is still poorly understood in Baviaanskloof. Therefore, this study sought to illuminate some of these complexities by investigating the spatial distribution and demographic variation across different landscape types (fynbos, savanna, thicket, forest, and agricultural land). This study will examine whether the behaviour of baboons varies spatially and temporally across different landscape types.

Baboons behave differently across different habitats and in different environmental conditions (Reed & Bidner 2004). Changes in the environment/different habitat types affect their foraging strategies, social dynamics, diet, habitat use, and learning and innovation (Audet & Lefebvre 2017). Extreme seasonal changes, such as an increase in rainfall during summer, and dry periods during winter also affect their behaviour (Van Schaik & Brockman 2005; Van Doorn et al. 2010). Consequently, baboons alter their feeding behaviour and exploit a range of natural and human-derived foods to cope with season that causes food scarcity (e.g. dry periods in winter) (Lewis & O'Riain 2017). They also alter their behaviour by spending more time socialising during longer days in summer compared to winter (Hill 1999; Hill et al. 2003; Chowdhury et al. 2021). Therefore, in this study, I expected the baboons to use savanna, forest, agricultural land (oil and lucerne), and thicket more than the fynbos landscape type, depending on the season (dry and wet), because resource availability varies in these landscape types due to different seasons. Baboons tend to select habitat based on the availability of resources that they require, including shelter, suitable sleeping sites, food, and water (Hamilton 1976; Barton et al. 1992). I also expected the landscape type utilisation to vary by sex and age because adult baboons are the ones that are known as frequent raiders, more especially the males than the young baboons. To add, females were expected to avoid risky areas when they have their young ones with them.

Outline of the thesis

The first data chapter of this thesis investigates chacma baboon (*Papio ursinus*) spatial distribution and demographic variation across landscape types, and the second chapter investigates spatial and temporal variation in the behaviour of chacma baboons. The two data chapters are written as scientific papers for publication, and thus, there is some unavoidable repetition in the methods sections. The results from this study will contribute to raising awareness, increase knowledge in the conservation, and management ideas to promote coexistence between humans and wildlife.

Aims and objectives

The aim of this study was to assess the spatial and temporal variation in baboon demographics in Baviaanskloof, Eastern Cape, South Africa, using camera traps.

Objectives

The specific objectives of this thesis were:

1. to describe the spatial distribution of baboons across different landscape types (fynbos, savanna, thicket, forest, and agricultural land),
2. to describe the demographic variations of baboons across landscape types, and
3. to investigate whether the behaviour of baboons varies across landscape types, seasons, and land-use types.

Hypotheses

It was hypothesized that;

I. Baboons would have different distribution patterns based on landscape type and landscape utilisation would vary in age and sex of baboons. Additionally, adult females, juveniles, and infants would utilise forested areas more, including savanna while most baboon groups would utilise all landscape types with high utilisation of savanna, thicket, and agricultural;

II. baboon behaviour would vary across different landscape types and different seasons.

It was expected that baboons would exhibit increased feeding and movement in lucerne, savanna, oil, forest, and thicket during the wet season, driven by the higher resource availability during this season, while in the dry season, baboons would primarily use lucerne and savanna landscape types for feeding and movement behaviour, attributing this to the seasonal abundance of resources (such as food) within these specific landscape types.

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Chapter Two: Methods and materials

Study area

This study was conducted in the Baviaanskloof in the Eastern Cape province, South Africa (Figure 1). The area consists of privately owned farmlands in Baviaanskloof Hartland and protected wildlife land within the Baviaanskloof Nature Reserve (Figure 2). Enclosing 1,234 km², the Baviaanskloof Nature Reserve is the fourth largest protected area in South Africa and is declared a UNESCO World Heritage site because of its cultural and natural diversity (Boshoff 2005; Boshoff 2008). The Baviaanskloof is classified as a semi-arid ecosystem comprising of two mountain ranges running from East to West namely the Baviaanskloof mountains in the North and the Kouga mountains in the South, as well as the Baviaanskloof River, and mountainous watersheds (Boshoff et al. 2001). The diversity of landscapes and land uses in this area is also reflected in climatic variability, and a diverse geology and topography. The mountain peaks comprise of rugged terrain with ridges formed by granite rocks (sandstones), plateaux with poor fertility soil (low clay), steep valleys, and alluvial fans on the valley bottom (Boshoff et al. 2001; McManus 2009; Glenday 2015).

Figure 1: Map of South Africa, Eastern Cape showing Baviaanskloof (red arrow) situated in the lower reaches of the Eastern Cape (Glenday 2015).

Figure 2: Baviaanskloof Nature Reserve (green outline), Baviaanskloof Hartland Conservancy (blue outline), and private properties (black outline) (Maya Beukes).

Climate

Local climate is determined by factors such as latitude, altitude, proximity to bodies of water, and topography (Glenday 2015). Climate plays a crucial role in shaping the environment, ecosystems, and human activities in a particular area. Baviaanskloof is a semi-arid region with warm summers (December to February), maximum temperatures reaching 45°C (ECPB 2007), and relatively cold winters (June to August) with daily temperatures ranging from 5°C to 31°C (McManus 2009). Average annual temperatures range from 17°C to 18°C (Buckle 1989). Higher altitudes experience much lower temperatures, usually below 13°C, causing mountain peaks to occasionally be covered with snow (ECPB 2007; Duker et al. 2015). Baviaanskloof experiences rainfall throughout the year, with peak precipitation occurring in March and November (Reeves & Conradie 2023). Rainfall in this area varies with gradient, meaning that higher slopes receive more rain approximately 800 to 1000 mm per annum than the low-lying slopes, which receive 300 to 400 mm per annum (Powell et al. 2011). Even the two mountain ranges that surround the Baviaanskloof receive varying rainfall, where the North-facing Baviaanskloof mountains receive an average of 451 mm per year, while Kouga mountains to the South receive 547 mm per year, with 300 mm per year in the West and 500 to 700 per year in the East (Euston-Brown 2006; ECPB 2009; Powell 2009). Baviaanskloof frequently experiences floods after heavy rainfalls events (Smith-Adao 2016) and droughts (Scheltema 2007).

Topography

The Baviaanskloof mountain ranges with its ridges and peaks were formed by the sandstones of the Cape Fold Belt (Boshoff et al. 2001), which was formed by the massive uplifting and faulting of supercontinent Gondwana in 430 to 330 mya (Maud 2008). The highest peaks in this area reach 1758 m (Smutsberg) and 1626 m (Scholtzberg) above sea level (Rust 1998). The Baviaanskloof lithology includes quarzitic sandstones, tillites, shales of the Table Mountain, and Enon conglomerate (reddish in colour) formed by eroded fault basins (Rust & Illenberger 1989; Rust 1998). Within this region, six distinct topographic landforms prevail and these include: alluvial fans, hillslopes, floodplains, high plateaus, cliffs, and canyon floors (Figure 3) (Glenday 2015). Notably, hillslopes constitute the largest portion at 40% of the area, succeeded by high plateaus at 29% (Glenday 2015). Cliffs encompass 17% of the landscape, while floodplains, canyon floors, and alluvial fans collectively occupy 15% of the terrain (Van den Bos et al. 2006; Clark et al. 2009; Fenicia et al. 2008b; Savenije 2010; Glenday 2015; Gao et al. 2014).

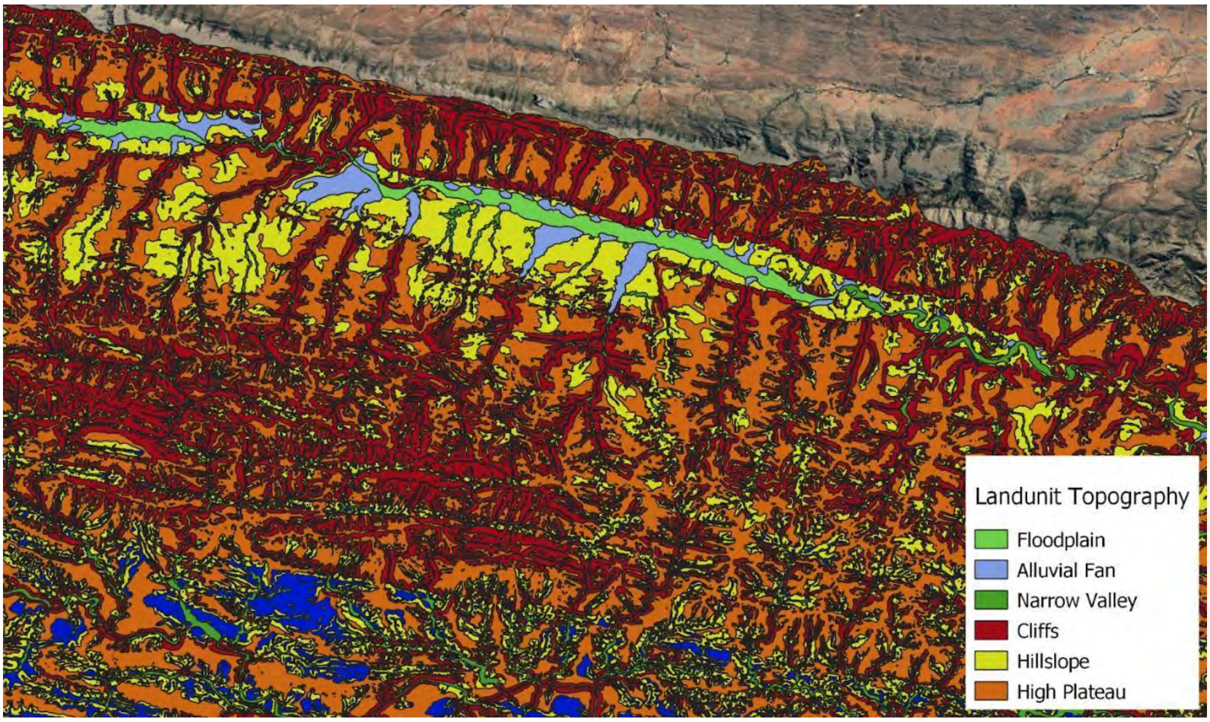

Figure 3: A map showing different topographic landforms found in the Baviaanskloof area (Maya Beukes).

Vegetation

Baviaanskloof is characterised by mosaic vegetation types with seven of the eight biomes that are found in South Africa being present (Mucina & Rutherford 2006). In this study, I focused on six landscape types including three vegetation biomes (Fynbos, Forest, and Savanna), land use type (agricultural land) (Figure 4), and a disturbance category (intact thicket and degraded thicket) (Boshoff et al. 2000). Vegetation types within Baviaanskloof vary depending on the topography of the area, with riparian forest being situated in deep narrow gorges between mountains, and the mixture of woodland, and savanna is in the valley-bottom (Boshoff & Cowling 2005). Large succulent and woody shrubs preside in the subtropical thicket that usually dominates in cliffs and hillslopes, and mountainous (plateaus and upper slopes) areas comprise of fynbos that consists of herbs and small-leaved woody shrubs (Boshoff & Cowling 2005). The privately owned lands belong to the farmers who farm domestic ungulates (sheep and goats), cattle, fruit, and vegetables (Boshoff et al. 2000). The fauna that is found in Baviaanskloof, including baboons, relies on these vegetation types for water, shelter, food, and all other resources that they require. Each of these vegetation types is described in detail below to give an overview of the study site.

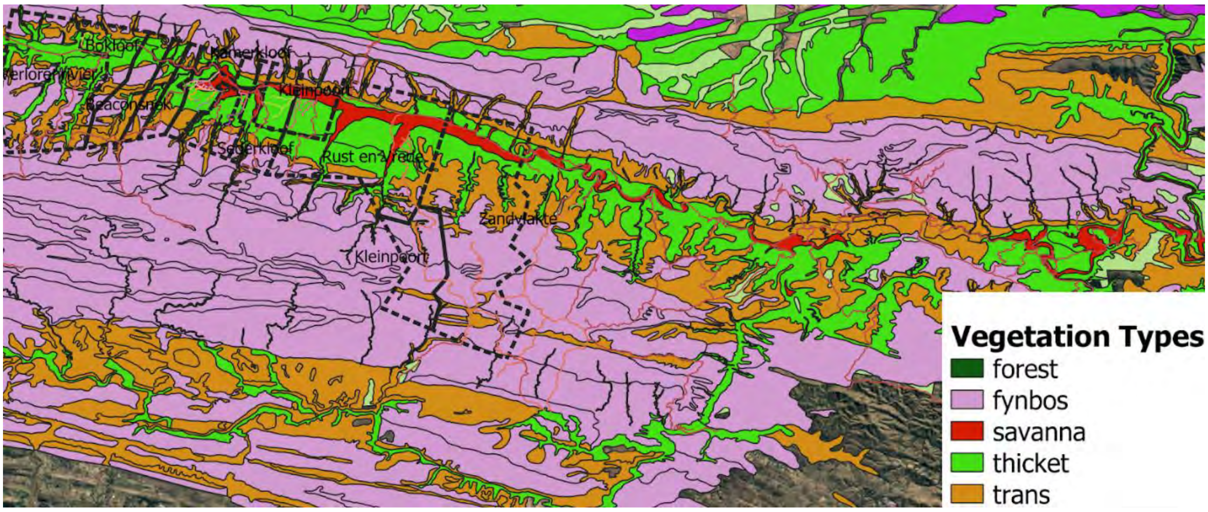

Figure 4: A map showing different vegetation types found within Baviaanskloof (Maya Beukes).

Fynbos

Fynbos (Figure 5) is characterised by nutrient-poor soil derived from sandstones and shales on mountainous areas (plateaus and upper slopes) (Euston-Brown 2006). The plant species found in the Fynbos include Restios, Ericas, and Proteas, these are the plants that have high tolerance in harsh conditions like low rainfall, higher temperatures, and higher winds (Boshoff et al. 2000; McManus 2009). Small-leaved woody shrubs, grasses, and herbs are the dominant plants in the Fynbos, with high drought-resistant features and generally 1-2 m tall, while grass being moderately present (Boshoff & Cowling 2005; Euston-Brown 2006). Baviaanskloof Fynbos is considered pristine because there are few palatable plants for forage, as such, the biome largely remains unfarmed and poorly developed (Glenday 2015).

Figure 5: Fynbos with small-leaved woody shrubs, grasses and herbs (Photo credit: Maya Beukes).

Forest

Riparian forests (Figure 6) are usually found in deep narrow gorges between mountains with the canopy that reach a length of >20 meters (e.g. fig trees (*Ficus carica*), sweet thorn (*Vachellia karoo*), white stinkwood (*Ceitis africana*), and real yellowwood (*Podocarpus latifolius*)) (Manning 2001). The base being occupied by shorter shrubs (e.g. *Carissa bispinosa*) and the ground cover is made up of grasses such as white buffalo grass (*Megathyrsus maximus*), rhodes grass (*Chloris gayana*), blue buffalo grass (*Cenchrus ciliaris*), bottle brush grass (*Anthephora pubescens*), small buffalo grass (*Megathyrsus coloratum*), and smutsvinger grass (*Digitaria eriantha*) (Pers. comm. Luyanda Luthuli), as well as herbs and ferns (Manning 2001). The forest gorges usually have rivers or streams that are flowing down within them that form alluvial fans when they reach the bottom parts of the area (Glenday 2015).

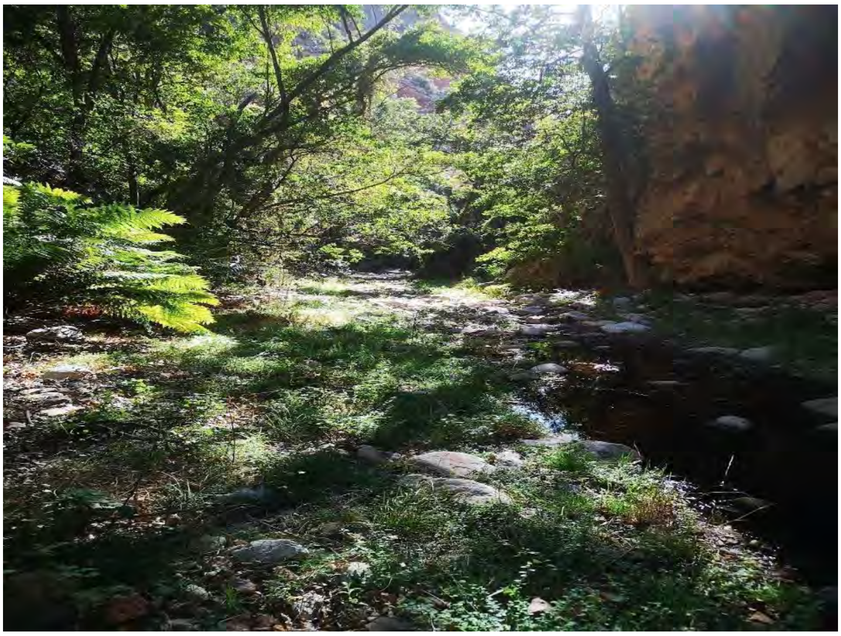

Figure 6: Forest with tall canopy, ferns, grasses and herbs (Photo credit: Maya Beukes)

Savanna

The Savanna biome (Figure 7) is found in the valley-bottom and it is highly characterized by sweet thorn which can reach up to 3 m in height, with large open grassy ground spaces (Manning 2001). The C4 grasses dominate this biome and the biome has a distinct upper layer of trees and thorny shrubs (Manning 2001). The sections of the Savanna biome in the Baviaanskloof are usually near the streams and rivers and this increases the chances of them being transformed into agricultural lands, and they have fertile soils, making them a good area to be converted to farmland (Manning 2001).

Figure 7: Tall *Vachellia* dominating the Savanna, and open grassy spaces (Photo credit: Maya Beukes).

Agricultural land

Agricultural land refers to savanna/woodland plains in lower altitudes with high fertile grounds that have been converted to livestock (e.g., goats, sheep, ostriches, and cattle) and crop (e.g., olives, rosemary, lucerne, and corn) farming (Figures 8 and 9) (Boshoff et al. 2000; Ndeketeya 2012).

Figure 8: Agricultural land with rosemary plants growing (Photo credit: Maya Beukes).

Figure 9: Livestock (goats) feeding in a transitioned savanna to agricultural land (Photo credit: Maya Beukes).

Intact thicket

Intact thicket is dominated by evergreen succulent trees, euphorbias, aloes such as *Aloe vera*, and *A. barbadensis miller*, spekboom, shrubs, and vines (Figure 10) (Manning 2001). Intact thicket is regarded as naturally fire-resistant because many plants store water in their pseudo-leaves, thus, they do not depend on precipitation to grow and flourish (Euston-Brown 2006). Lastly, intact thicket is pristine and dense with thorny shrubs that protect themselves from herbivory and has rich nutrient plant species, and provides cover for small mammals (e.g. rodents) (Manning 2001).

Figure 10: Pristine intact thicket dominated by thorny shrubs and spekboom (Photo credit: Maya Beukes)

Degraded thicket

Thicket dominates cliffs and hillslopes, it is characterized by woody shrubs and large succulents, including *Grewia robusta*, *Brachylaena ilicifolia*, and renosterbos (*Elytropappus rhinocerotis*) (Manning 2001). The spekboom (*Portulacaria afra*) is the most common species in the Thicket biome, it is highly adaptable to harsh and dry environment (Manning 2001). However, due to overstocking which led to overgrazing by small livestock, large tracks of Thicket have become degraded, the water table has dropped, and there are high levels of erosion (Figure 11) (Lechmere-Oertel et al. 2005; Mills et al. 2005). As a result, many plants are no longer able to grow in these degraded habitats. There is a lot of exposed soil in the degraded habitats and farmers have started planting spekboom to reduce water run-off and the speed and energy of water falling from the mountain to the bottom (Pers. obs. 2023).

Figure 11: Severely degraded thicket with dry exposed topsoil and few shrubs still standing (Photo credit: Maya Beukes).

Methods

Experimental design and data collection

Baviaanskloof consist of two sections, namely, Baviaanskloof Hartland agricultural area and Baviaanskloof Nature Reserve. The land use in Baviaanskloof Hartland agricultural area comprises of various anthropogenic activities, including livestock farming, resting (i.e. no longer used for agricultural purposes), and non-utilised (i.e. land has never been used). While the Baviaanskloof Nature Reserve is used for wildlife and is protected under the jurisdiction of the Eastern Cape Parks and Tourism Agency. This study was conducted in the Baviaanskloof Hartland area section only. A stratified random sampling approach was used to determine the camera trap locations in this section according to the vegetation biomes (Fynbos, Forest, and Savanna), land use type (agricultural land), and the degradation category between degraded thicket and intact thicket.

Thirty camera traps, consisting of Bushnell (2), Acorn (1), and Cuddeback (27) were placed across the Baviaanskloof Hartland area in each selected camera trap location (i.e. one camera per camera location) from February 2020 to April 2022 (Figure 12). Camera locations were grouped as study location 1 (SL1), study location 2 (SL2), and study location 3 (SL3) for monitoring purposes within the Hartland area. The thirty camera traps were placed and rotated across the three study locations (SL1, SL2, and SL3) by moving a number of camera traps from one study location to another to maximise animal capture rates, and to cover both summer and winter seasons at each of these locations. Overall, study location 1 (SL1) consisted of 27 camera locations, study location 2 (SL2) had 34 camera locations, and study location 3 (SL3) encompassed 29 camera locations, covering both summer and winter seasons. The duration of camera trap deployment varied across study locations due to theft, animal interference, and camera malfunctions (Table 1). At each camera trap location, the camera was placed at 50 cm from the base of the tree, and secured against the tree, or iron or wooden poles, and/or fence posts were used if there was no suitable tree in the selected location. Each camera was positioned facing either South or North to prevent overexposure and shadow from sunlight. Precautions were taken to remove vegetation that could trigger the cameras unnecessarily, and metal security boxes were used to shield the cameras from potential damage by wildlife and harsh weather conditions. The cameras operated continuously for 24-hour periods, with their detection range tested by walking and crawling past them. Movements were recorded at 30-second intervals, and all images were stored on 32GB SD cards. Camera sites were visited every 30 to 45 days to download data, replace batteries when necessary, ensure proper functioning, and address any damage or vegetation interference (Kok 2016). Upon retrieval, data were downloaded and organized in Microsoft 365 Excel, with filenames, indicating the time, date, and camera site. The data were then sorted and cleaned using R-studio 4.3.2 (RCore Team 2023) for further analysis, with *tidyr* and *collapse* packages being used for cleaning the data. During the study period (February 2, 2020, to April 4, 2022), a total of 90 camera trap locations were surveyed (Beukes unpublished PhD).

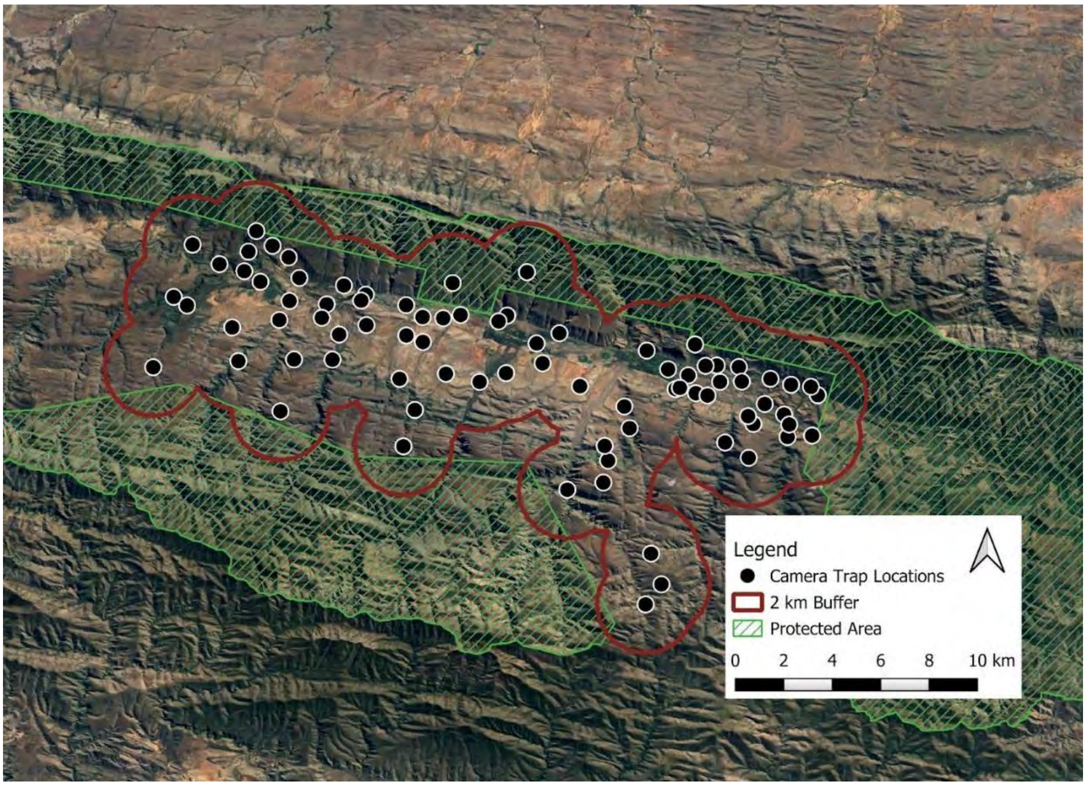

Figure 12: Baviaanskloof Hartland study area map showing camera trap placements (black dots), protected area (green), and the 2 km buffer area where camera traps were placed (Maya Beukes).

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Appendix

Table 1: Duration of camera traps (camera trap nights) across study locations and the mean of camera running time.

Study location 1		Study location 2	Study location 3
195	220		203
185	115		203
199	161		76
199	61		161
198	137		259
190	185		163
200	176		181
200	159		63
162	247		180
192	162		202
7	122		202
199	177		202
195	143		57
203	157		128
198	66		96
199	183		117
198	42		203
174	116		158
200	111		120
63	92		92
200	148		128

28	128	120
186	168	199
202	183	175
199	177	215
200	122	216
	183	168
	182	146
	185	207
	181	
	177	
	161	
Study location	**Mean of the camera running time**	
SL1	**176**	
SL2	**151**	
SL3	**160**	

Chapter Three: Chacma baboon (*Papio ursinus*) spatial distribution and demographic variation across landscape types

Abstract

Chacma baboons occur widely in southern Africa. Their flexible and opportunistic feeding behaviour allows them to easily adapt to diverse habitat conditions, readily switching their diets in response to extreme seasonal changes in food availability. They select habitats based on the availability of resources that they require, including shelter, suitable sleeping sites, food, and water. The extent to which baboons utilise different habitats has not been well explored, particularly in Baviaanskloof, where baboons are abundant. As such, in this study, I explored the spatial distribution and demographic variations of baboons across landscape types (fynbos, savanna, thicket, forest, and agricultural land). The specific objectives were to; a) scrutinise the spatial distribution of baboons across landscape types, and b) assess the demographics of baboons across landscape types. It was hypothesised that baboon spatial distribution would vary across different landscape types, and this would be based on age and sex. It was further hypothesised that adult females, juveniles, and infants would utilise forested areas more, while most baboon groups would utilise any landscape type, with more utilisation of agricultural land. To attain my objectives, camera traps were placed on a stratified random layout for two years (February 2020 to April 2022) in the Baviaanskloof area. During this time, baboons utilised agricultural land and forest more than other landscape types. As predicted, adult females, juveniles, and infants significantly used the forested area, including savanna while adult males, sub-adult males, and sub-adult females used savanna, thicket, and agricultural land more. These results suggest that baboons in Baviaanskloof use agricultural lands and landscape types such as savanna and forest, which are near water sources. This leads to higher baboon abundance and distribution in these landscapes and potentially increased human-wildlife conflict, specifically in the agricultural lands. The results may contribute to the conservation of baboons in the area since the findings indicate their distribution estimation.

Key words: landscape types, spatial variation, abundance, distribution, human-wildlife conflict, demographics, crop-raiding

Introduction

The chacma baboon (*Papio ursinus* – baboons hereafter*)* is the most widespread baboon in southern Africa (Skinner & Chimimba 2005; Stuart & Stuart 2015; Sithaldeen 2019), occupying a wide range of habitats including riverine forests, woodlands, savanna, grasslands, and mountainous areas (Kummer 1968a; Zinner et al. 2001; Stuart & Stuart 2015; Sithaldeen 2019). Baboons are abundant and found throughout the Eastern Cape, mostly in rugged cliffs, wooded areas, and in protected areas (Hill 1997; Fehlmann et al. 2017a; Fehlmann et al. 2017b). They are generalist feeders, and flexible enough to effectively adapt to high numbers of anthropogenic activities (Whiten et al. 1991; Jolly 2001; Codron et al. 2006; Codron et al. 2008; Bergman & Kitchen 2008; Warren 2009; Hoffman & O'Riain 2012a). Due to their abundance and widespread nature, they are regarded as pests and problematic species (Hill 2000; Lee & Priston 2005), and are categorised as species of least concern by both the International Union for Conservation of Nature (IUCN) Red List and the South African Mammal Red List (Whiten 1991; Jolly 2001; Friedmann & Daly 2004; Codron et al. 2006; Codron et al. 2008; Hoffman & Hilton-Taylor 2008; Sithaldeen 2019).

Habitat selection is a complex process influenced by a combination of ecological, social, and behavioural factors that help animals optimise their survival and reproductive success in their natural environments (Montgomery & Roloff 2017). Baboons tend to select habitat based on the availability of resources that they require, including shelter, suitable sleeping sites, food, and water (Hamilton 1976; Barton et al. 1992). They show a strong preference for environments characterised by rocky cliffs and tall trees, which serve as refuges during times of threat and for night-time rest, given their diurnal nature (Cheney et al. 1987; Stuart & Stuart 2015). Inhabiting rocky cliffs and tall canopies helps baboons evade predators such as leopards, humans, and domestic dogs (Zinner & Pel´aez 1999; Zinner et al. 2001; Zinner et al. in press). Additionally, baboons are susceptible to temperature fluctuations, and the utilisation of rocky cliffs creates microhabitats that offer refuge from both extreme heat and cold (Stelzner 1988; Barrett et al. 2003). Thus, inhabiting woodland areas provides shade (Stelzner 1988) and helps moderate temperatures by reducing the impact of direct exposure to sunlight and insulating the ground. When temperatures are extremely low or high, baboons spend most of their time resting (Stoltz & Saayman 1970; Bernstein 1972; Bernstein 1975; Clutton-Brock & Harvey 1977) and grooming (Hill 2006) instead of foraging activities. Although thermal conditions may play a role in habitat selection, predation risk is ultimately the most critical factor in some areas that have predators. When selecting a habitat, proximity to a water source is also crucial because baboons rely on drinking water for survival (Stuart & Stuart 2015; King 2016). In instances where they are distant from water sources, they ensure hydration through the consumption of moisture-rich foods such as wild fruits like prickly pear (*Opuntia spp.*) (Kummer 1968a; Zinner et al. 2001; Stuart & Stuart 2015).

By choosing habitats with abundant resources, baboons increase their chances of finding enough food to eat, water to drink, and safe places to rest (Altmann & Altmann 1970; Hamilton et al. 1978; Post 1978; Rasmussen 1979; Whiten et al. 1987). While this is the case, resource availability is sometimes affected by extreme seasonal changes, such as an increase in rainfall during summer and dry periods during winter, causing food scarcity (Van Schaik & Brockman 2005; Van Doorn et al. 2010). Optimal foraging theory suggests that natural selection favours individuals that are able to efficiently acquire the most energy while minimising the time and energy spent searching for and handling food (Stephen & Krebs 1986). To minimise the costs while foraging, baboons select food items that provide the highest energy return per unit of effort (e.g. choosing larger or more nutritious food items) (Hoffman & O'Riain 2012b), adjusting their foraging effort in response to changes in food availability, and optimising their movements and habitat use patterns to efficiently exploit resources (Stephen & Krebs 1986). Since baboons are generalists, they are able to adjust to numerous habitat conditions, where they easily switch their diets during extreme seasonal changes to food availability in a particular period (Whiten et al. 1987; Else 1991; Whiten et al. 1991; Henzi & Barrett 2003; Alberts & Altmann 2006). During summer season, they feed on a wide variety of non-indigenous foods (human-derived foods such as garbage, crops from orchards) and indigenous foods (wild fruits, seeds, leaves, and roots) that they find, whereas in the winter season, they switch their diets to non-seasonal insects, barks, and available grass depending on their African location (Terborgh 1983; Terborgh 1986; Terborgh & van Schaik 1987; Altmann & Muruthi 1988; Forthman & Demment 1988; Hill et al. 2000; Kansky & Gaynor 2000). Resource availability and shortage are sometimes caused by anthropogenic activities (bulldozing natural water holes) and natural occurrences like flooding, causing some resources to become locally exhausted by animals that are using them (Hamilton et al. 1976). The flexibility and opportunistic feeding behaviour of baboons allows them to eat a multitude of different foods (Alberts & Gaillard 2018) and to thrive in various environments, including human-modified environments, and causes them to exploit human foods (Falls 1993; Fehlmann et al. 2017a). They use their opportunistic foraging strategies to meet their energy requirements (Huey & Pianka 1981).

The transformation of natural habitats to human-modified environments at a global level has posed a huge problem to many animal species (Clutton-brock & Harvey 1977; Paterson et al. 2005; Woodroffe et al. 2005; Slater et al. 2018), with habitat fragmentation, urbanisation, and habitat destruction being the major threats to the population of many animals currently. Some of these animals, including primates (e.g. Eastern gorilla (*Gorilla beringei*), Guinea baboon (*Papio papio*), Mandrill (*Mandrillus sphinx*) etc) are considered threatened, vulnerable, and critically endangered (Whiten et al. 1991; Jolly 2001; Codron et al. 2006; Codron et al. 2008). The transformation of natural habitats to human-modified habitats could result in changes in the foraging behaviour of some species, resulting in human-wildlife conflict (Slater et al. 2018). These conflicts could be exacerbated when resources are scarce (i.e., during dry season), and species could resort to easily accessible resources to minimise the time spent obtaining the food (Stephen & Krebs 1986). Food resources from human-modified landscapes such as plantations, vineyards, homes, commercial properties, garbage disposal sites, and picnic or camping sites (Hill 2000; Kansky & Gaynor 2000; Pahad 2010; Hoffman & O'Riain 2010) have high energy content and are easily digested. Incorporating these food sources into the diet of baboons could alter their reproduction behaviour in such a way that females might fail to raise their offspring successfully, and the timing of mating seasons can be delayed or be early, and reproduction may increase (Strum 1994). Human activities can lead to the fragmentation of baboon social groups as they are forced to move into smaller, more isolated areas (Slater et al. 2018).

The Baviaanskloof is an important area to study and understand the behavioural ecology of baboons. It is a remote area located in the Eastern Cape province, South Africa. The area remained largely uninhabited for many years because of its remoteness and inaccessibility, but that changed during the nineteenth and twentieth century when the human population was estimated to be 2000 individuals (Boshoff 2008; Webley 2011b). The Baviaanskloof is home to a number of wildlife species, and some of these species are found in and outside the protected area (Van Jaarsveld 2011). A high number of endemic plants have been recorded in the area (Boshoff 2008; Van Jaarsveld 2011; Eastern Cape Parks & Tourism 2018). The area comprises different landscapes and land uses with a mosaic of vegetation types. With riverine areas experiencing ecotone (Vlok 1989), where three or five vegetation types are present within a short distance (e.g. forest, thicket, grassland, and savanna) (Vlok 1989; Euston-Brown 2006; Rebello et al. 2006; Van Jaarsveld 2011), the differences in biomes, landscapes and land uses have been expanded in Chapter two. The main source of income in this area is livestock and crop farming, and the tradition of farming has been passed down across generations to sustain their livelihoods (Urquhart 1990).

Baviaanskloof is known as the "Valley of Baboons" because of their abundance in the area. While this is the case, the number of baboons in the area is not known, and this makes it challenging to manage the baboons in the area. Given the culture of farming in the area, baboons are exposed to cultivated foods, and this could affect their feeding ecology, particularly in the dry season when resources are scarce. Baboons can exploit anthropogenic food resources when these are readily available to them, and this usually causes human-wildlife conflict (Falls 1993; Strum 1994; Naughton-Treves et al. 1998; Hoffman & O'Riain 2010). However, the influence of these land-use changes on baboon behaviour is not well understood and this poses limitations on the ability to effectively manage baboons in Baviaanskloof across land-use types, including inside and outside of protected areas (Tscharntke et al. 2012; Lambin & Meyfroidt 2011). Understanding the relationship between land-use and how baboons utilise different landscape types in Baviaanskloof is important to determine which land-use practices are most sustainable for both private farmers and the community and to implement management strategies that support the co-existence of humans and wildlife. To address this gap in knowledge, this study investigated the distribution of baboons across different landscape types, and the specific objectives were; a) to assess the spatial distribution of baboons across landscape types (fynbos, savanna, thicket, forest, and agricultural land), and b) to investigate the demographics of baboons across landscape types. It was hypothesised that baboons would have different distribution patterns based on landscape type, and landscape utilisation would vary according to the age and sex of baboons, for example, adult females and their juveniles and infants would utilise forested areas more to avoid riskier areas and a bit of savanna, while most baboon groups would utilise any landscape type, with more utilisation of savanna, thicket, and agricultural land.

Methods

A detailed description of the study site and the methodology employed for sampling technique is provided in Chapter 2.

Data analysis

To assess the spatial distribution and demographic variation of baboons across landscape types, images of baboons were retrieved from the camera traps. For each photo, camera-site, date, photo number, time of the day, landscape type, season, land-use, study location, levels of degradation, camera nights, and demographics were recorded. In instances where multiple photos were taken in short period of time (few seconds before next capture), they were treated as a single capture (Tambling et al. 2015). To further process these data, baboons were classified as either: a) adult male (25 – 45 kg, and total length 120 – 160 cm) recognised by the size (very big), highly pronounced dog-like muzzle, and a mane of long-hair on the shoulders and neck; b) adult female (12 – 20 kg, total length 100 – 120 cm), recognised by one smaller pad on each buttock which gets puffy and turns scarlet during gestation period, size (big but smaller than males), with a short muzzle; c) sub-adult male was characterized by a longer snout, growing mane and looking like an adult male but small by size; d) sub-adult female were characterized by looking similar to adult females but smaller in size; e) juvenile was characterized by fully grey grown hair in the body and being independent, they are usually in groups playing while; f) infants were not fully grown, they had black hair with pink faces and were fully dependent on their parents; g) unknown, the picture not clear enough to be able to identify the sex and age of the baboon but they were included in the analysis (Kansky 2002; Stuart & Stuart 2015).

To assess the spatial distribution of baboons across the landscape types, namely, agricultural land (lucerne and oil were combined due to having less camera trap locations), savanna, forest, thicket (degraded and intact thicket combined) and fynbos. I used the Kruskal-Wallis test for comparing the distribution of baboons across landscape types and one-way ANOVA test to assess their spatial distribution. Additionally, I used Linear Mixed Effects Model (R package *lme4*, *lmerTest*, *Matrix*, and *nlme*), and for this analysis, the total number of baboons was the dependent variable, landscape type was independent variable, and camera location was kept as a random variable to see how much of the difference between landscape types is due to variation in camera locations within landscape types. I performed pairwise comparison using the command *emmeans* (package *emmeans*) to assess the difference in total number of independent captures of baboons across landscape types. I followed the same analysis procedure for each baboon demographic to assess the relationship between landscape type and demographic use.

Baboon demographics were assessed by counting the total number of baboon independent captures per camera location across the different age groups per landscape type. However, the number of days the camera traps were active varied across landscape types, therefore, the total number of baboon independent captures were converted to photo rate using the following formula : $\frac{each\ demographic}{camera\ nights} * 1000$ (Photo rates were calculated per 1000 trap nights instead of 100 to avoid very small decimal values) this was done for each camera site. Additionally, I calculated the relative abundance indices (RAI) for each baboon demographic which were obtained by dividing the number of independent captures of baboons by total number of camera nights multiplied by one hundred. In addition to this, a two-way ANOVA (the total number of baboons was the response variable, landscape type and demographics were the independent variables) was used to assess variation in baboon demographics across landscape types namely, agricultural land (lucerne and oil were combined due to having less camera-trap locations), savanna, forest, thicket (degraded and intact thicket combined), and fynbos. A TukeyHSD test was performed to determine which specific age groups were significantly different from each other.

Prior to the analysis, normality tests were conducted using a Q-Q plot and if data were not normally distributed, they were log-transformed or alternative non-parametric tests were used. All data analysis were performed in R version 4.3.2 (RCore Team 2023) with α set at 0.05.

Results

Spatial distribution of baboons across landscape types

In total, there were 21100 temporally independent captures of baboons. Baboons showed significantly higher distribution in agricultural land, followed by forest, savanna, and thicket landscape types, with the lowest distribution in the fynbos landscape (Figure 1). Kruskal-Wallis test shows that indeed there was a difference between landscape types (Kruskal-Wallis, $X^2 = 21.79$, df = 4, p = 0.0002). There was a significant difference in baboon numbers (i.e. independent captures) across landscape types ($F_{3,77} = 7.2$, $p<0.001$). Pairwise comparison showed that baboons utilised agricultural land, forest, savanna, and thicket (degraded and intact thicket combined) significantly more than fynbos (Table 1).

Table 1: Pairwise comparison between landscape types for baboons' total photo rate.

Contrast	estimate	SE	Df	t-ratio	p-value
Forest - Fynbos	2.2690	0.582	77	3.902	0.0011
Fynbos - Savanna	-2.3176	0.548	77	-4.231	0.0004
Fynbos - Thicket	-1.4850	0.480	77	-3.097	0.0142
Agri - Fynbos	3.2564	0.782	77	4.472	0.0002

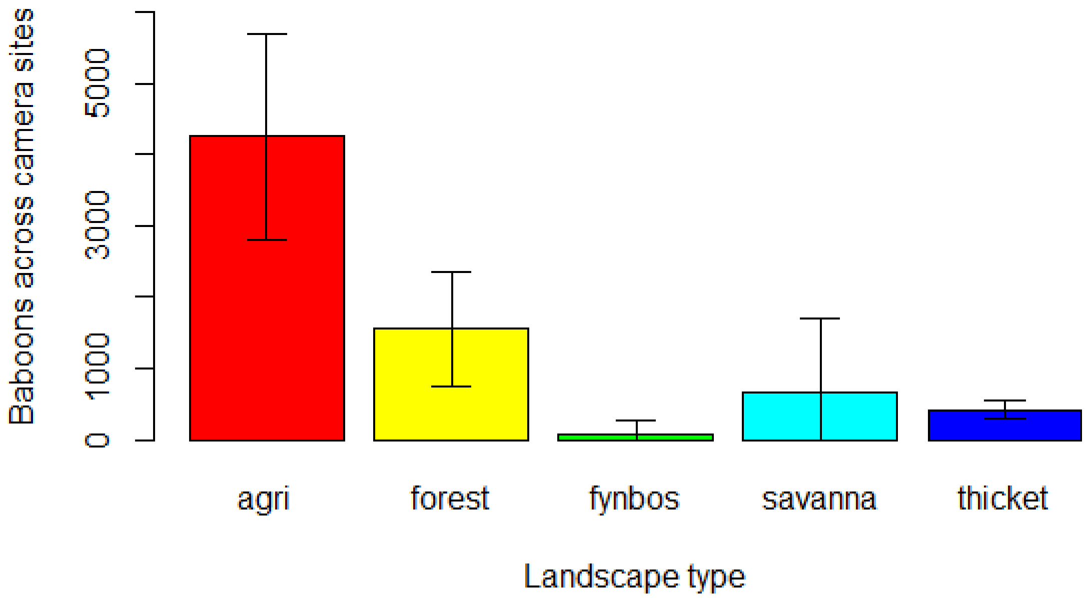

Figure 1: Total baboon photo rate across camera trap locations by landscape type. Baboon distribution and utilisation across different landscapes in the Baviaanskloof Hartland area. Oil and lucerne landscape types were merged together as agricultural land (agri = agricultural land). Error bars represent Standard Errors.

Baboon demographics across landscape types

A total of 21100 independent baboon captures were estimated in Baviaanskloof throughout the study period and the baboons were classified into seven groups (Table 2). Of these groups, adult females (51.05 (RAI) (proportion of photo captures)) were more abundant, and there were few infants (0.11 (RAI) (proportion of photo captures)) compared to other groups. Demographics were distributed differently across landscape types (Table 3), with adults (male and female) having a high relative abundance index in savanna, agricultural land, and forest, while juveniles had a high relative abundance index in agricultural land and forest. While sub-adults had a high relative abundance index in the agricultural land. Demographic groups displayed a significant variation (F_{31} = 15.43, p < 2e-16) (this was a main effect only) in their use of the different landscape types, as predicted, adult females, juveniles, and infants showed a high utilisation of savanna and forest (Figure 2). While adult males, sub-adults (males and females) were found in savanna, agricultural land, and thicket.

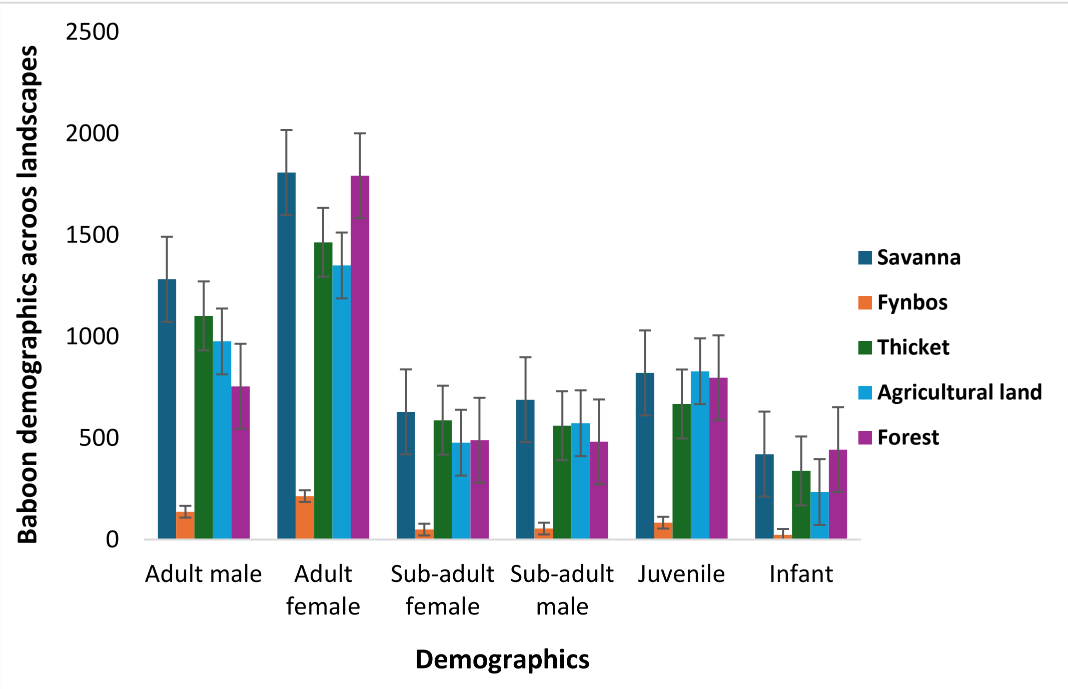

Figure 2: Total number of independent baboon captures per landscape type. Error bars represent Standard Errors.

Table 2: Overall summary of baboon independent captures, demographics, and relative abundance index (RAI).

Demographics	Baboon independent captures	RAI
Adult male	4177	32.17

Adult female	6628	51.05
Sub-adult male	2358	18.16
Sub-adult female	2232	17.19
Juvenile	3198	24.63
Infant	1487	11.45
Unknown	1020	7.86
Overall total	**21100**	**162.52**
Total number of camera nights	**12983**	

Table 3: Variation in distribution of baboon demographics across landscape types with the percentage per landscape type in brackets (%), and relative abundance index (RAI). Oil and lucerne landscape types were merged together as agricultural land. (Highest RAI in bold).

Demographics	**Savanna**	**RAI**	**Fynbos**	**RAI**	**Thicket**	**RAI**	**Agricultural land**	**RAI**	**Forest**	**RAI**
Adult male	1282 (23%)	**23**	137 (24%)	**24**	1102 (23%)	**23**	976 (22%)	**22**	755 (16%)	16
Adult female	1808 (32%)	**32**	214 (38%)	**38**	1464 (31%)	**31**	1350 (30%)	**30**	1792 (38%)	**38**
Sub-adult female	629 (11%)	11	49 (9%)	9	588 (12%)	12	477 (11%)	11	489 (10%)	10
Sub-adult male	689 (12%)	12	54 (10%)	10	561 (12%)	12	573 (13%)	13	481 (10%)	10
Juvenile	821 (15%)	15	83 (15%)	15	668 (14%)	14	829 (19%)	19	797 (17%)	17
Infant	421 (7%)	7	23 (4%)	4	338 (7%)	7	234 (5%)	5	443 (9%)	9

Discussion

Overall, there was a significant variation in the distribution of baboons across landscape types, with a strong utilisation of agricultural land, forest, and savanna more than other landscape types and this supports my hypothesis. As predicted, adult females, juveniles, and infants utilised the forest and savanna more while adult males, sub-adult males, and sub-adult females used any landscape type, with more utilisation of savanna, thicket, and agricultural land more than other landscape types.

Baboon distribution across different landscape types in Baviaanskloof

My results demonstrate variation in the distribution of baboons across different landscape types, where baboons utilised agricultural land, forest, and savanna more than other landscape types, which supports my hypothesis. Baboons make adjustments to take advantage of new landscape types with plenty of food resources that can be found easily by raiding (Chowdhury et al. 2020). The high amount of time spent by baboons in the agricultural land, forest, and savanna could be caused by food availability because baboons are opportunistic feeders (Alberts & Gaillard 2018), are fond of crops, and are attracted to seasonal foods (e.g. fruits) (Fehlmann et al. 2017a; Fehlmann et al. 2017b). Baboons can exploit risky human-modified environments, including commercial farms (Hill 2000; Kansky & Gaynor 2000; Warren 2009; Hoffman & O'Riain 2010; Pahad 2010; Van Doorn et al. 2010; Fehlmann et al. 2017b). They are regarded as the most problematic crop-foraging animals and they damage crops more than any crop-foraging animal (Findlay 2016), and their presence on the farm can reduce plant diversity and alter the physical structure of the landscape. Farmers in Baviaanskloof experience crop raiding problems by baboons on a daily basis, and this creates human-wildlife conflict. The frequent use of the forest by baboons could be linked to the availability and use of cover as their refuge, and safe place to retreat into at night, and when they feel threatened by potential predators (Hill 2006; Stuart & Stuart 2015). It is possible that forest provides safe sleeping sites for the baboons because of its dense cover which provides warmth during lower temperatures (Hill 2006), and shade during higher temperatures (Stelzner 1988), baboons also use forest for foraging since they feed on leaves, seeds, roots, barks, and shoots (Stuart & Stuart 2015). Additionally, the forest landscape type is always found near the rivers which is convenient for baboons because it is essential for them to drink every day, even though staying close to the water source can lead to more intensive use of riparian vegetation (Kummer 1968a; Zinner et al. 2001; Stuart & Stuart 2015). When they are far from the river or during dry seasons, they find other ways of getting water (e.g. feeding on plants that have high water content) (Kummer 1968a; Zinner et al. 2001; Stuart & Stuart 2015), they also use savanna landscape type if there are scattered tall trees for sleeping. Baboons were not abundant in the thicket and fynbos landscape types. In the fynbos landscape type, found on high-plateaus and upper mountain slopes, there is not much food available for baboons and water is not readily available (Glenday 2015), so they rely on artificial ponds or dams. Therefore, this might be the reason why baboons were not widely distributed in the fynbos landscape type. The thicket landscape type is quite similar to fynbos but better, with water not being readily available, but it has food for baboons (Glenday 2015), this might have caused them not to be much distributed in this landscape type.

Landscape type utilisation by different baboon age groups and sexes

The results show a significant landscape type and demographic interaction which supports the hypothesis. As expected, there was a variation in baboon demographics across landscape types, with some baboons, particularly males, sub-adult males, and sub-adult females, showing high utilisation of agricultural lands. Fehlmann et al. (2017b) found that adult male baboons spend most of their time exploiting human-modified environments, and adult males are known as frequent raiders. My results also show this pattern of adult males spending more time in agricultural lands, adult males are the ones that go first and stay near the area that they want to exploit and wait until the opportunity to raid arises (Strum 1994; Hill 2000; Van Doorn et al. 2010; Warren 2009; Fehlmann et al. 2017b). The adult males alert the rest of the troop to come and raid (Fehlmann et al. 2017b). Adult males are the leaders of the troop (Mazué et al. 2023), but there is always one dominant alpha male (Stuart & Stuart 2015), the dominant male makes decisions about the troop movement, and adult females and their infants are always close to this male for their safety (DeVore & Washburn 1963; Kansky 2002). Adult females and their infants showed high utilisation of the forest and savanna, as anticipated. Females are particularly mindful of their surroundings due to their young, making it essential for them to avoid areas that could pose risks to themselves and their infants. Baboons have learned to adapt and use human-modified landscape types and these landscape types offer food that is easily accessible, highly nutritious, digestible and always found in larger quantities (Duhem et al. 2008). Sub-adult males and sub-adult females utilised agricultural land more than other landscape types, and this could be linked to the fact that they also spend time exploiting anthropogenic landscapes along with adult males.

Factors affecting landscape type selection on baboons

Baboons choose their landscape type based on resources availability (Stephens & Krebs 1986; Hill 2005; Strandburg-Peshkin et al. 2017), thermal cover (Wheeler 1994; Barrett et al. 2003; Hill 2006), predation risk (Kummer 1968a; Altmann & Altmann 1970; Partridge 1978; Belovsky 1984; Post 1984; Cowlishaw 1997; Hill 2006; Stuart & Stuart 2015; Strandburg-Peshkin et al. 2017), and social dynamics. When feeding, baboons tend to prioritize energy and time spent while searching and handling food and that results in them utilising landscape types that have more resources (Stephens & Krebs 1986; Sol et al. 2013). These landscape types are usually found in riskier environments for them to be present in, such as private and protected lands in Baviaanskloof. For example, if baboons would be given access to fynbos landscapes and agricultural land, they would prefer to forage in agricultural areas, as demonstrated by the results shown in Figure 1, which indicates a greater distribution of baboons in the agricultural land. This behaviour may be influenced by resource availability across landscape types, as baboons tend to select areas with abundant resources to improve their chances of finding sufficient food and water while minimizing the time spent searching (Hoffman & O'Riain 2012b). In contrast, fynbos, with its low-quality food resources, would require much more time for foraging (Kruger 1977; Davidge 1978; Stock & Allsopp 1992; Coetzee et al. 1997; Rebelo et al. 2006; Hoffman & O'Riain 2011). Baboons residing near human settlements opt for easy ways of getting food, which is raiding from homes, picnic sites, farms, directly from people, and commercial properties (Hofman & O'Riain 2010), and this gives rise to human-baboon conflict that leads to baboons being killed (Beamish & O'Riain 2014). Previously, farmers in Baviaanskloof, farmed fruit (Urquhart 1990) but this had stopped because of extensive crop raiding (Pers. comm. Dawid Smith). Vervet monkeys (*Chlorocebus pygerythrus*) and baboons would enter and steal crops and the population of both species has increased in the area (Pers. comm. Dawid Smith). The drought that has affected this area over the past decades has had a significant impact on farmers, making it difficult for them to grow fruits and vegetables due to the high input effort and maintenance required (Illgner & Haigh 2003; Knight 2012). In spite of crop raiding and drought, a number of farmers, in Baviaanskloof are still farming olive oils, lucerne, and rosemary, although baboons have a significant impact on their farms.

Implications and management strategies for protected landscape types utilised by baboons

Managing protected landscape types utilised by baboons requires a better understanding of their ecological roles and the potential impacts of their activities. In some cases, it is the baboons or wildlife at large that first occupy the area then humans arrive and convert the natural landscape type in a way that suits them (Illgner & Haigh 2003). For example, in Baviaanskloof, most of the savanna landscape types were converted/transformed into agricultural lands. In addition, humans have introduced their foods to wildlife by planting crops and farming livestock, which has caused human-wildlife conflict in the area (Urquhart 1990). Now that the introduction of new/foreign foods has taken place, there is a need for strategies to promote the coexistence of humans and wildlife in the Baviaanskloof. Getting a detailed understanding of the behaviour of baboons will shed light on how they are affected by changes in land use in this area, as it is still poorly understood, and there have been no thorough studies on these ubiquitous species, which makes it challenging to protect them and protect private areas from them.

Baviaanskloof farmers have been complaining about baboons raiding their private lands and properties (Pers. comm. Dawid Smith) and in this study, the results show that indeed baboons do cause problems in the area by being present frequently in agricultural lands. Future studies should take into account time spent in human-modified environments compared to other landscape types and take a thorough look at the utilisation of these landscape types by different age groups and sexes to give a broad understanding of baboon behaviour. Such knowledge can contribute to raising awareness and implementing effective conservation strategies in the area. Management decisions should consider additive or complementary approaches to keep the baboons out of the private lands in Baviaanskloof. Many useful management strategies such as baboon fencing, bin proofs, paintball guns, and field rangers to monitor baboons have been used in areas such as the Western Cape (Cape Town) Cape Peninsula, Tokai area, George campus of Nelson Mandela University, and many other places and these management strategies worked effectively (Fehlmann et al. 2017b). Future studies could use the existing data, then test methods that could work to improve coexistence between humans and baboons. These methods or management strategies could include paintball markers as an aversive technique to assist in keeping baboons out of farms or private lands, fencing to prevent them from jumping over the fence, bin proofing to avoid attracting them, and burglar bars for doors and windows to protect their private properties. Some of these management strategies are more expensive to other community members but they can make a huge difference in arresting the issue of baboons in the Baviaanskloof.

Conclusion

The results from this chapter revealed that baboons in Baviaanskloof utilise agricultural lands, as well as savanna, and forest. Additionally, careful attention should be attributed to the conservation of baboons in this area because the increase in their population would exacerbate the issues and challenges of human-baboon conflict in Baviaanskloof. This study provides insights into the population demographics and landscape type use of baboons and this will help in developing appropriate management strategies that could be effective enough to allow the coexistence of farmers and baboons in Baviaanskloof. Developing appropriate management strategies can be done by using the already known information about baboons to address the human-baboon conflict. The results will also help raise awareness, increase knowledge in conservation and provide management ideas to promote coexistence between humans and wildlife. Long-term study on baboon demographics, behaviour and ecology is essential in this area for conservation initiatives as it has been done in other areas that have baboon problems.

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Appendix

Table 4: P-values from the post hoc test for landscape types and demographics.

Landscape types	Demographics	p-value
Thicket: Forest	Adult female (af)	0.0270337
Forest	Infant (infa) and adult female	0.0218109
Thicket: Forest	Infant (infa) and adult female	0.0123422
Forest	Sub-adult female (sbf) and adult female	0.0159065
Forest: Fynbos	Juvenile (juv) and adult female	0.0112698
Savanna: Fynbos	Juvenile (juv) and adult female	0.0009840
Thicket: Fynbos	Juvenile (juv) and adult female	0.0086346
Lucerne: Fynbos	Sub-adult male (sbm) and adult female	0.0000138
Lucerne: Fynbos	Unknown (unkn) and adult female	0.0031319
Oil: Lucerne	Infant (infa) and adult female	0.0006560
Oil: Lucerne	Sub-adult male (sbm) and adult female	0.0098245
Lucerne: Oil	Adult male (am) and adult female	0.0025202

Chapter Four: Does the behaviour of chacma baboon (*Papio ursinus*) vary spatially and temporarily across landscape types and seasons?

Abstract

Seasonal fluctuations and landscape transformations in the Baviaanskloof, Eastern Cape, South Africa shape the behaviours of chacma baboons (*Papio ursinus*), revealing how this species copes with dynamic environmental conditions. Change in season alters their behaviour, such as feeding, causing them to travel long distances to get resources, such as water and food, and they also shift habitat use and inhabit advantageous areas. In the Baviaanskloof, areas of natural habitats, have been transformed into anthropogenic habitats such as agricultural lands. However, the extent to which these conversions of natural habitats affect the behaviour of baboons is poorly understood. Therefore, this study investigates whether baboon behaviour varies seasonally (wet and dry seasons), across different landscape types and according to land-use. I hypothesised that baboons would exhibit increased feeding and movement in lucerne, savanna, oil, forest, and thicket during the wet season, driven by the higher resource availability during this season. While in the dry season, they would display increased feeding and movement in lucerne and savanna landscape types, attributing this to the seasonal abundance of resources (such as food) within these specific landscape types. I further predicted that baboons would utilise forest landscape types for sleeping, grooming, and resting behaviours during both the wet and dry seasons, as this is the safe (place of refuge) landscape type for them. To assess the patterns of baboon behaviours and land use, camera traps were placed on a stratified random layout for two years, February 2020 to April 2022, in the Baviaanskloof Hartland area. Results indicate that baboon behaviour fluctuated seasonally between landscape types. As predicted, baboons utilised forest, lucerne, savanna, and thicket landscape types more frequently than other landscape types during the wet season. Whereas, in the dry season, they utilised lucerne, thicket, forest, and savanna landscapes. Baboons were observed sleeping more frequently in the forest landscape and to a lesser extent in the savanna landscape during the wet season. Their preferred use of savanna and forest landscapes is likely due to the availability of suitable roosting sites. They also exhibited resting and grooming behaviour more in the forest during the wet season as anticipated. These results show that the behaviour of baboons in Baviaanskloof is influenced by the changes in season and landscape types, causing them to change their foraging strategies and look for resources in a landscape that provides resources in and out of season. These findings may contribute to the conservation of baboons in the area since the findings indicate their distribution and utilisation estimation across different landscape types and seasons.

Key words: behaviour, landscape types, seasonal fluctuations, natural habitats, land conversion

Introduction

Behavioural flexibility is a sign of cognitive complexity in animals like primates (Emery & Clayton 2004; Amici et al. 2008). This is particularly important in environments that are subject to frequent changes, such as those impacted by human activities (Wong & Candolin 2015). Various factors drive primates' flexibility at an ecological level (Van Schaik 1989; Sterck et al. 1997; Koenig 2002), and these include temperature, resource availability, diversity, group size, predation pressure, and the condition of the environment (Van Schaik et al. 1983; Gesquiere et al. 2008). These factors play a key role in the flexibility of behaviour in primates as they are likely to behave differently across different habitats and in different environmental conditions (Reed & Bidner 2004). This adaptability helps primates navigate and survive in diverse and changing conditions, and it can be observed in various ways, such as dietary adaptation, social dynamics, habitat use, foraging strategies, and learning and innovation (Audet & Lefebvre 2017).

Baboons are widely distributed, with high behavioural flexibility and ecological adaptation, exhibiting a variety of behavioural adaptations, which facilitate their survival in changing conditions of diverse environments (Stuart & Stuart 2015; Fischer et al. 2019). Their adaptability to diverse environments can be a function of flexible foraging strategies and diet (Whiten et al. 1991). They exploit a range of natural and human-derived foods; hence they are widely known to have broad-based diets even in sometimes resource-constrained habitats (Lewis & O'Riain 2017). They use both terrestrial and arboreal routes to exploit various food sources and can adapt their foraging techniques based on seasonal fluctuations (Stephen & Krebs 1986; Whiten et al. 1987; Else 1991; Whiten et al. 1991; Henzi & Barrett 2003; Alberts & Altmann 2006). Change in season alters their feeding behaviour, causing them to travel long distances to get resources, such as water and food, and they also shift habitat use and inhabit advantageous areas (Alberts et al. 2005). Seasonal changes can also lead to the raiding of human-derived foods because high-quality human food is readily available in and out of season (Altmann & Muruthi 1988). Baboons , particularly those found in southern parts of Africa tend to invest more of their time in feeding, travelling and socialising due to longer days in summer (wet season) than in winter (dry season) (Hill 1999; Hill et al. 2003; Chowdhury et al. 2021). They have developed strategies to avoid predators, such as living in large groups ranging from a few individuals to over a hundred, which make up a troop and this is an adaptation behaviour to survive (Stuart & Stuart 2015).

Chacma baboons are extremely social, and they display various social behaviours, such as vocal communication, grooming, playing, fighting, resting, sleeping, feeding, and submission (Darwin 1872; Zuckerman 1932; Bolwig 1957; Silk et al. 2003; Silk et al. 2009; Silk et al. 2010). Baboons tend to be most active just after dawn (Anderson & McGrew 1984) and throughout the day and then retreat to their sleeping sites by early dusk (Stuart & Stuart 2015). Males primarily exhibit behaviours, such as vocalisation, fighting, threatening, and yawning (Kansky 2002). Fights typically begin between two males, often over a female or food, and when one male starts to lose, he calls for help, prompting more baboons to join the conflict until it escalates into a group fight (Zuckerman 1932). Aggressive behaviour over food within the troop is usually because of competition due to food scarcity in the environment (Fessler 2002; Vitousek et al. 2004). Furthermore, conflict also occurs due to dominance hierarchy, where the dominant male or female has priority in mating, first access to food and water, and preferred sleeping sites (Barton 1993; Bergman et al. 2003; Cheney et al. 2004; Jolly 2007; Alberts & Altmann 2012; Stuart & Stuart 2015; Alberts & Gaillard 2018). Females are unlikely to exhibit play and fight behaviour (Leresche 1976), but they tend to display grooming behaviour most within troops, spending about 5-15% of their time in grooming (Bolwig 1957; Bronikowski & Altmann 1996; Alberts et al. 2005). Playing behaviour can be observed in both adult baboons and young ones, but it is particularly prominent in early infants and peaks during the juvenile stage (Bekoff & Byers 1981; Fagen 1981; Fairbanks 2000). This behaviour can take the form of object play, solitary play, or social play (Graham & Burghardt 2010).

Several underlying factors can affect spatial utilisation and alter baboon behaviour, these factors include the availability of resources such as food, and water, the presence of predators, and anthropogenic activities (Lee 1997; Menard & Vallet 1997; O'Brien & Kinnaird 1997; Singh et al. 2001; Ganas & Robbins 2005; Li et al. 2005; Li & Rogers 2005; Wieczkowski 2005). The distribution and abundance of food resources strongly influence how baboons use their space and sometimes they expand or contract their range depending on food availability (Brennan et al. 1985; Saj et al. 1999; Hill 2005; Riley 2008). Access to water is crucial to them, especially in arid environments, as a result, they often centre their activities around reliable water sources (Kummer 1968a; Zinner et al. 2001; Stuart & Stuart 2015). The presence of predators alters baboon behaviour in such a way that they tend to avoid regions or to stay closer together in larger groups for safety and they prefer areas with trees, cliffs, or other features that protect them from predators (Zinner & Pel´aez 1999; Zinner et al. 2001; Zinner et al. in press). In addition, human activities such as development and land use changes can reduce available habitat, forcing baboons to alter their movements and behaviour (Hockings & McLennan 2012). As a result, they end up raiding agricultural fields because of easy access to food (Kansky & Gaynor 2000; Hill 2000; Pahad 2010; Hoffman & O'Riain 2010), which leads to conflicts with humans (Slater et al. 2018; Hill 2000). Increased human presence through tourism or other interactions can habituate baboons to humans, altering their natural behaviour and spatial use (van Doorn & O'Riain 2020; Cape Peninsula Baboon Strategic Management Plan 2023).

The Baviaanskloof has different anthropogenic activities (i.e. agricultural activities and wildlife reserve for conservation and ecotourism), and these have increased over time with the increase in human population (Illgner & Haigh 2003). The extent to which these anthropogenic activities alter the behaviour of baboons in Baviaanskloof remains poorly understood. Therefore, understanding baboon behaviour across different landscape types, land uses, and seasons is crucial, as their foraging strategies change with the seasons and the environment, often leading to conflict with humans. To contribute to this knowledge gap, the present study examined whether the behaviour of baboons varies spatially and temporarily. The objective of this study was to investigate whether the behaviour of baboons varies across landscape types, seasons, and land use, using camera traps for a period of two years (February 2020 to April 2022). I hypothesised that baboon behaviour would be influenced by different landscape types and different seasons since seasonal fluctuation alters their behaviour, causing them to travel long distances to get resources, such as water and food, and they also shift habitat use and inhabit advantageous areas when resources are scarce. I predicted that baboons would exhibit more feeding and movement behaviour in lucerne, savanna, oil, forest, and thicket during the wet season, driven by the higher resource availability during this season, while in the dry season, they would display feeding and movement primarily in lucerne and savanna, attributing this to the seasonal abundance of resources (such as food) within these specific landscape types. I further predicted that baboons would exhibit sleeping, grooming, and resting behaviours more in forest landscape types during both the wet and dry seasons, as this is the safe (place of refuge) landscape type for them. The results from this study will contribute to a better understanding of baboon behaviour, and how the season and landscape type influence their behaviours in Baviaanskloof. The findings will also contribute to the conservation of baboons in different areas that are occupied by baboons.

Methods

A detailed description of the study site and the methodology employed for sampling technique is provided in Chapter 2.

Data analysis

Data processing

To investigate whether the behaviour of baboons varies spatially and temporarily, images of baboons were retrieved from the camera traps. For each photo, camera site, date, time of the day, landscape type, season, land use (e.g. land used or not used), study location, levels of degradation, camera nights, behaviour, and the number of behaviours per picture were recorded. In instances where multiple photos were taken in a short period of time (a few seconds before the next capture), they were treated as a single capture (Tambling et al. 2015).

Classification of behaviours

To further process these data, baboon behavioural categories were classified and modified based on Bolwig's (1957) ethogram.

Table 1: Detailed classification of observed baboon behaviours from camera trap photos.

Behaviour	Observation
Grooming	Two or more baboons searching each other's fur using their hands, licked and bit the hair, ticks and anything found in the fur and skin.
Feeding	The behaviour was observed when a baboon was investigating and/or eating a food item.
Moving	The behaviour was observed whenever baboons were walking and jumping.
Playing	The behaviour was observed when baboons played in groups or individually using objects (metal/wooden poles, sticks, and fence).
Fighting	The behaviour was observed when two or a group of baboons were fighting.
Sleeping	The sleeping behaviour was observed when baboons were sleeping, mostly during dusk, night until dawn (when they wake up), since some camera traps were placed nearby their roosting sites.
Resting	The behaviour was observed on independent photo captures when baboons were inactive or sitting idle for about 30 minutes in multiple independent photo captures, and it primarily occurred during the day. This behaviour was observed on the timestamp of the first photo to the last as the baboon remained in the same posture.

Seasonal categories classified

I divided the seasons into, wet and dry based on the collected photo data. Seasons were determined by the amount of rainfall that occurs each month throughout the year. The wet season is characterised by high rainfall, which occurs from September to March with 35°C temperatures, while the dry season is marked by low rainfall, which occurs from April to August, with low temperatures of 5°C (McManus 2009).

Statistical analysis

To assess the variation in the behaviour of baboons across landscape types namely, savanna, fynbos, forest, oil, lucerne, and thicket as well as seasons (i.e. dry and wet seasons), Generalised Linear Mixed Effects Model (R package *lme4*, *glme*) were used. For analysis in this chapter, the behaviour of baboons was specified as the response variable, while landscape type and season were fixed effects, and land use (e.g. land used or not) was kept as a random variable. Generalised Linear Mixed Effects Model binomial link function was used to assess if the landscape type and season influenced the behaviour of baboons. Land-use was used as a random variable to determine whether it influence the behaviour of baboons across landscape types, because it differed across landscape types (e.g. some Thicket parts being non-used, while some are used for farming). Additionally, landscape types in Baviaanskloof were either used (e.g. for farming), not used (e.g. non-use land), and resting (e.g. land no longer used for agricultural purposes). I performed a pairwise comparison using *lsmeans* (package *lsmeans*) to assess the behavioural differences between season and landscape type (Appendix 1). I then visualised the overall behaviours and differences by plotting the graphs using the *ggplot2* package.

Before analyses were performed, data were tested for normality using a histogram and Q-Q plot. All statistical analyses were conducted in R version 4.3.2 (R Core Team 2023), with α set as 0.05.

Results

The overall behaviour of baboons

The behavioural patterns of baboons varied (Figure 1), and the most frequently observed behaviour was movement, followed by feeding. Additionally, resting behaviour was observed slightly more often than playful behaviour. Conversely, grooming, sleeping, and fighting occurred less frequently than the other behaviours.

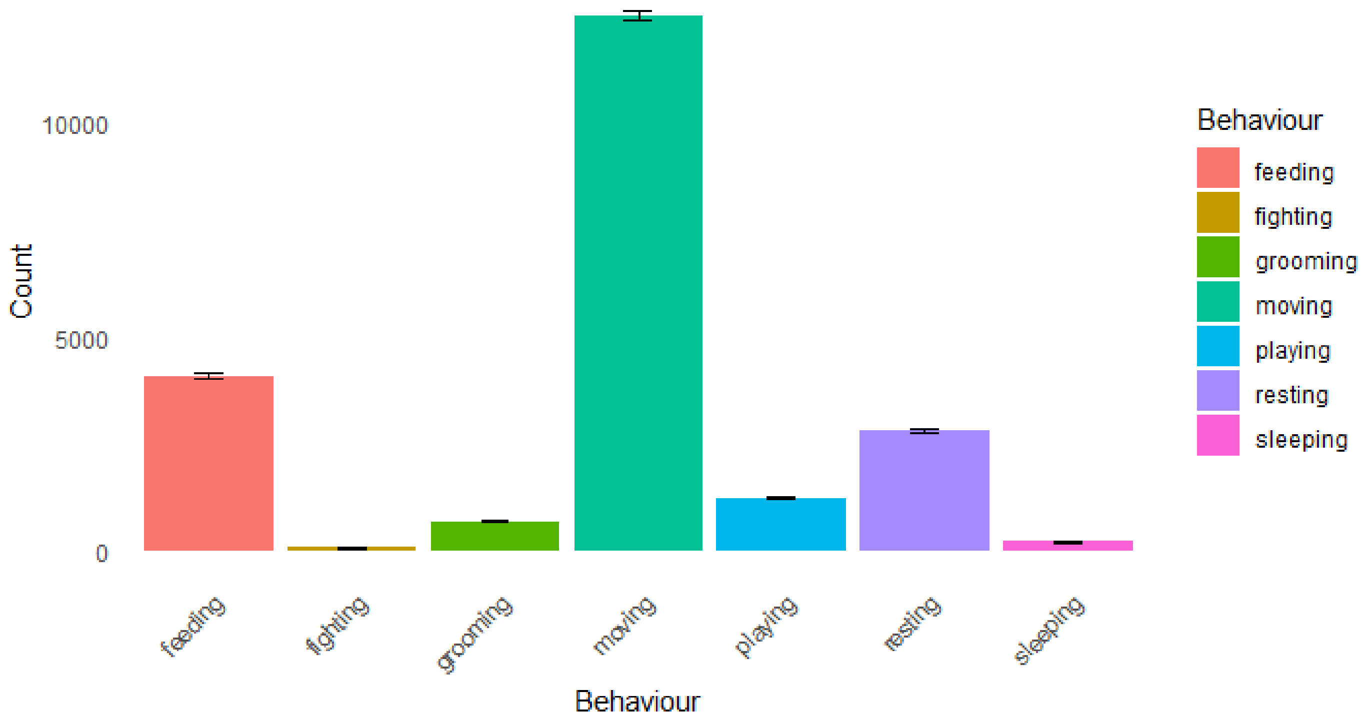

Figure 1: Count (number of each behaviour) of baboon behaviour from independent photo captures of baboons. Error bars represent Standard Errors.

Behaviour of baboons across landscape types and between seasons

A total of 21100 independent baboon captures were estimated in Baviaanskloof throughout the study Period. Baboon behaviour differed across landscape types and seasons (F_5 = 37.64, p<0.001; Figure 2; Appendix 1). As predicted, baboons spent most of their time moving and feeding in the forest, lucerne, thicket, and savanna during the wet season. Additionally, they rested more in the forest and lucerne, and less in the savanna and thicket landscape type during the wet season. In the dry season, baboons slightly fed and moved in the lucerne, thicket, forest, and savanna. There was a significant difference in baboon behaviours, with baboons displaying sleeping, grooming, and resting behaviours more frequently in the forest landscape type during the wet season than in the dry season (Figure 2). They also displayed playing behaviour and it was high in the thicket compared to the forest, lucerne, and savanna during the wet season. They displayed fighting behaviour only in the forest during the wet season.

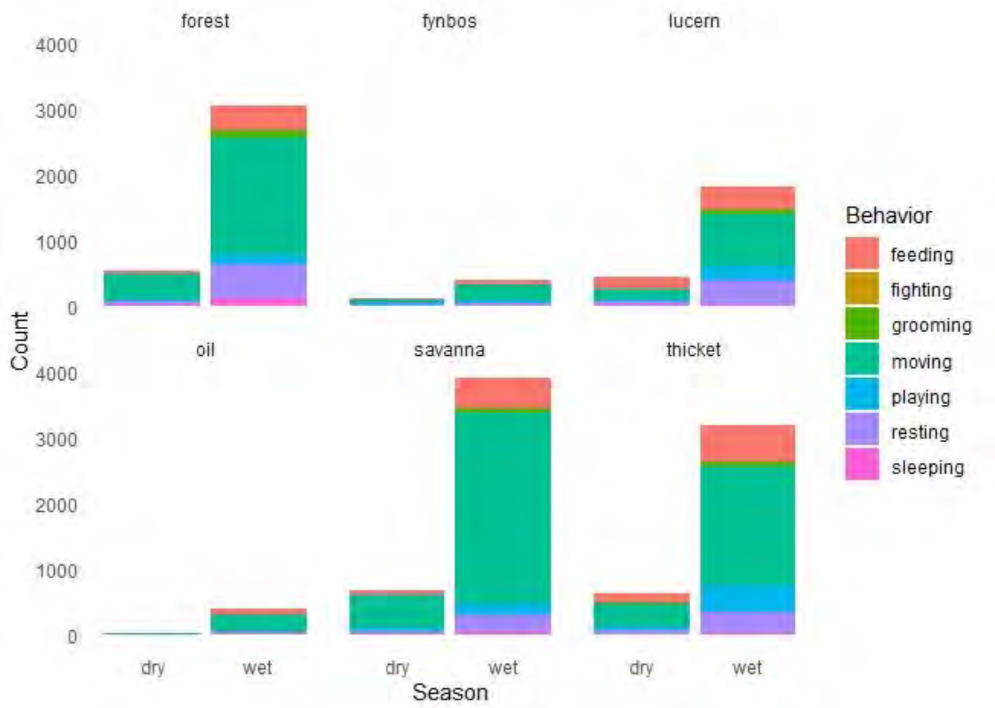

Figure 2: Count (number of each behaviour) of baboon behaviour across different seasons and landscape types from independent photo captures of baboons.

Discussion

My results suggest that the behaviour of baboons in Baviaanskloof is influenced by different landscape types and fluctuations in season, as such, they behaved differently across these and this result is in agreement with my hypothesis. As predicted, baboons exhibited feeding and moving behaviour more in the forest, lucerne, savanna, and thicket during the wet season, while in the dry season, they slightly exhibited moving and feeding in the lucerne, thicket, forest, and savanna. Baboons exhibited sleeping behaviour more frequently in the forest landscape type and to a lesser extent in the savanna during the wet season compared to other landscape types. They also exhibited resting and grooming behaviour more in the forest during the wet season as I anticipated. Overall, these results suggest that baboons change their foraging strategies and look for resources in a landscape that provides resources in and out of season.

Behavioural patterns of baboons

Baboons are highly active displaying various behaviours (Silk et al. 2010), such as grooming, playing, fighting, resting, sleeping, feeding, submission and more (Bolwig 1957). In the results, the most frequently observed behaviour was moving, which indicates their active nature and tendency to explore their environment. Following moving behaviour, feeding was the next most common activity, underscoring the importance of foraging in their daily routines (Stephen & Krebs 1986), baboons make a lot of movements when in search of food (Fehlmann et al. 2017b). Resting behaviour was also observed slightly more than playing behaviour, reflecting the balance these animals maintain between activity and rest, they usually spend time resting during high or low temperatures (Bernstein 1975; Clutton-Brock & Harvey 1977). It is essential for their well-being and energy conservation. The less frequency in the exhibition of grooming, sleeping, and fighting behaviours might be due to these behaviours occurring only under specific circumstances or social contexts. Grooming behaviour, for instance, serves to strengthen social bonds (Bolwig 1957; Alberts et al. 2005) and to remove ectoparasites from each other (Cheney & Seyfarth, 2007). Sleeping behaviour starts at early dusk until after dawn (Stuart & Stuart 2015). Fighting behaviour usually starts when there is competition over resources which is sometimes caused by food scarcity in the environment (Vitousek & Manke 2004) and fights can also erupt due to dominance hierarchy (Alberts & Altmann 2012). Overall, this pattern of behaviour highlights the dynamic social structure and environmental interactions of baboons in their natural habitat.

The influence of seasonal fluctuations and landscape types on the behaviour of baboons

Changes in seasons affect baboons to the extent that they change their behaviours, such as feeding and foraging strategies to cope with the shortage of resources (Chowdhury et al. 2021). This observation is in agreement with my results, which showed that the use of landscape types by baboons is driven by season and hence resource availability. As much as baboons are highly adaptable to changing environments and extreme seasonal fluctuations (Whiten et al. 1987; Else 1991; Whiten et al. 1991; Henzi & Barrett 2003; Alberts & Altmann 2006), they allocate their foraging time deliberately, resulting in them utilising landscape types that will give them big reward with less time spent searching (Stephen & Krebs 1986; Maré et al. 2021). In this study, baboons fed and moved more in the thicket, savanna, forest, and lucerne landscape types during the wet season than the dry season as predicted (Figure 2), this could be caused by food availability, as these landscape types have plenty of food that falls under baboons' diet (Brennan et al. 1985; Stephen & Krebs 1986; Saj et al. 1999; Hill 2005; Riley 2008; Fehlmann et al. 2017a; Fehlmann et al. 2017b). In the Baviaanskloof, the savanna landscape type consists of grasses and sweet thorn, and both make up a substantial part of the diet of baboons, while thicket provides an abundance of plants with high water content, which helps baboons to get water since drinking water is crucial to their well-being (Kummer 1968a; Zinner et al. 2001; Stuart & Stuart 2015). Additionally, the forest landscape type consists of most of their food items, such as leaves, bulbs, and roots. In contrast, the lucerne landscape type is abundant with lucerne, which requires less effort for foraging since food is plentiful and readily available at all times. The same pattern has been observed in red-tailed sportive lemur (*Lepilemur ruficaudatus*), which adjust their ranging pattern during the wet season (Ganzhorn 2002). Vervet monkeys (*Chlorocebus pygerythrus*) also tend to alter their foraging strategies to follow different landscape types that provide abundant resources throughout the seasons (Teichroeb & Smeltzer 2018). The baboons slightly moved and fed in the forest, savanna, thicket, and lucerne during the dry season, which could be linked to the shortage of resources during the dry season. Although they fed and moved slightly in these landscape types, they fed and moved more in the lucerne during the dry season as predicted compared to other areas. This choice in baboons may be linked to the cultivation of lucerne by farmers in the Baviaanskloof, which is available in all seasons. When resources are scarce in their natural environment, baboons venture into human-modified environments to exploit high-energy-rich foods (Fehlmann et al. 2017b), meaning their utilisation of lucerne during the dry season in Baviaanskloof is associated with the shortage of food in their natural environments.

Baboons exhibited sleeping behaviour more frequently in the forest landscape type and less in the savanna during the wet season. This may be associated with their use of forest and savanna landscape types as sleeping sites, refuges, and a safe place to retreat to when they are threatened by predators (Hill 2006; Stuart & Stuart 2015). Baboons inhabit a variety of riverine forested landscape types and savanna/woodland landscape types (Stuart & Stuart 2015). These landscapes provide suitable roosting sites, with forests typically located near water sources, which is advantageous for them (Kummer 1968a; Zinner et al. 2001; Stuart & Stuart 2015; Sithaldeen 2019). Seasonal temperatures are a constraint on baboon behaviour, yet little attention has been given to them compared to other ecological factors (Hill 2006). In this study, baboons showed resting and grooming behaviours more in the forest during the wet season. This could be linked to their tendency to alter behaviours in response to high and low temperatures (Hill 2006). During high temperature extremes, baboons often engage in sedentary activities like grooming and resting to conserve energy (Stoltz & Saaymann 1970; Bernstein 1972; Bernstein 1975; Bernstein 1976; Hill 2006). Additionally, the forest landscape provides a safe environment for baboons, greatly reducing their chances of encountering humans and other potential predators (Cowlishaw 1997; Hill 2006; Stuart & Stuart 2015). As a result, they feel safer and can rest, sleep, and groom for extended periods in this type of landscape compared to others, the forest landscape type also provides cover for them (Hill 2006; Stuart & Stuart 2015). The same pattern has been observed in vervet monkeys (*Chlorocebus pygerythrus*) where they used landscapes with tall trees and that provide safety as a refuge in response to threat posed by their potential predators such as, martial eagles (*Polemaetus bellicosus*), crowned eagles (*Stephanoaetus coronatus*), and leopards (*Panthera pardus*) (Cheney & Seyfarth 1990; Isbell 1990). Baboons exhibited fighting behaviour only in the forest landscape. This could be associated with competition for resources and the usage of these resources based on hierarchy since dominant males and females have the advantage of first access to resources (Bergman et al. 2003; Alberts & Gaillard 2018). As much as the forest landscape is rich in resources (Cowlishaw 1997; Hill 2006; Stuart & Stuart 2015), feeding order is considered in the troop and deviations from this order often leads to a fight (Cheney & Seyfarth 2007). In addition, the fight within the troop also erupts when one adult or sub-adult male challenges the position of the dominant male (Cheney & Seyfarth 2007). Playing behaviour was relatively high in the thicket compared to other landscape types. Thicket landscape type in Baviaanskloof consists of brushes and shrubs (Manning 2001) with no big trees for putting up camera traps which has led to the use of iron/wooden poles. Therefore, due to curiosity baboons ended up using these iron/wooden poles to play, from the photo data collected showed baboons pulling them and climbing on them, especially the young baboons. This could be the reason why baboons exhibited playing behaviour more in the thicket landscape type.

The conversion of natural habitats, such as savanna and woodlands, into agricultural lands in Baviaanskloof has introduced wildlife, including baboons, to unfamiliar foods (human foods). As a result, baboons have become attracted to these foods, which are now available year-round. This has led them to rely on these foods as a backup during food scarcity. They alter their behaviours such as foraging strategies in trying to cope with a scarcity of resources, they often crop-raid and that always leads to human-baboon conflict. Similar behaviour has been observed in baboons on the Cape Peninsula, where they replaced their natural foods with anthropogenic foods due to water and food shortages, worsening the human-baboon conflict (Kaplan et al. 2011; Chowdhury et al. 2020).

Conclusion

This study showed that seasonal fluctuations and different landscape types in Baviaanskloof influence baboon behaviour. During the wet season, baboons tend to move and feed in the savanna, forest, thicket, and lucerne areas. This behaviour may be linked to the availability of resources in these landscapes. Additionally, during the dry season, they foraged and moved through various habitats, including thickets, savannas, forests, and lucerne. However, they spent more time feeding and moving in the lucerne areas. This suggests that they altered their feeding behaviour in response to food scarcity, seeking out landscapes that offered better forage, with the lucerne landscape being the most beneficial in this case. They also showed sleeping behaviour in the savanna and forest, and resting and grooming behaviour in the forest and this may be because these landscape types provide safe sleeping sites and refuge when they feel threatened. Future studies should look at seasonal fluctuations and landscape types at the demographical level to see how different baboon age groups react and deal with these factors, and to see which age group is highly affected by these factors in Baviaanskloof. Baboons are known to have high behavioural flexibility, which helps them cope with changing environmental conditions, but it would be helpful for future studies to also look at the effect of seasonal changes and landscape type on the physiology (glucocorticoids hormones) of baboon demographics in the Baviaanskloof. This study adds knowledge and provides insight into how the conversion of landscape types and seasonal changes alter the behaviour of baboons. Ultimately, these results demonstrate that baboons behave differently across different landscape types, seasons, and land uses and their behaviour alteration in trying to cope with environmental conditions, possibly raising conflicts with humans in Baviaanskloof. These human-baboon conflicts would be arrested by the implementation of management strategies such as baboon fencing, and bin-proofing.

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Appendix

Appendix 1. Tukey table results for baboon behaviour across landscape types and seasons. Statistically significant differences ($p<0.05$) are indicated in bold.

Landscape type x season	Estimate	SE	Df	z-ratio	p-value
Forest dry - Lucerne dry	1.85759	0.1940	Inf	9.579	**<.0001**
Forest dry - Thicket dry	1.11881	0.1830	Inf	6.103	**<.0001**
Forest dry - Fynbos wet	0.88375	0.2080	Inf	4.243	**0.0013**
Forest dry - Lucerne wet	0.91247	0.1770	Inf	5.162	**<.0001**
Forest dry - Oil wet	1.17596	0.2040	Inf	5.759	**<.0001**
Forest dry - Thicket wet	0.74628	0.1620	Inf	4.613	**0.0002**
Fynbos dry - Lucerne dry	1.02704	0.2660	Inf	3.863	**0.0063**
Lucerne dry - Savanna dry	-1.86275	0.1700	Inf	-10.961	**<.0001**
Lucerne dry - Thicket dry	-0.73878	0.1450	Inf	-5.101	**<.0001**
Lucerne dry - Forest wet	-1.44678	0.1340	Inf	-10.782	**<.0001**
Lucerne dry - Fynbos wet	-0.97384	0.1710	Inf	-5.699	**<.0001**
Lucerne dry - Lucerne wet	-0.94512	0.1150	Inf	-8.198	**<.0001**
Lucerne dry - Oil wet	-0.68163	0.1550	Inf	- 4.412	**0.0006**
Lucerne dry - Savanna wet	-1.55440	0.1250	Inf	-12.421	**<.0001**
Lucerne dry - Thicket wet	-1.11131	0.1230	Inf	-9.054	**<.0001**
Savanna dry - Thicket dry	1.12396	0.1660	Inf	6.751	**<.0001**
Savanna dry - Fynbos wet	0.88890	0.1890	Inf	4.698	**0.0002**
Savanna dry - Lucerne wet	0.91762	0.1500	Inf	6.127	**<.0001**
Savanna dry - Oil wet	1.18112	0.1820	Inf	6.499	**<.0001**
Savanna dry - Thicket wet	0.75144	0.1460	Inf	5.145	**<.0001**
Thicket dry - Forest wet	-0.70800	0.1170	Inf	-6.059	**<.0001**
Thicket dry - Savanna wet	-0.81562	0.1090	Inf	-7.502	**<.0001**
Thicket dry - Thicket wet	-0.37253	0.1070	Inf	-3.478	**0.0254**
Forest wet - Lucerne wet	0.50165	0.1080	Inf	4.666	**0.0002**
Forest wet - Oil wet	0.76515	0.1490	Inf	5.142	**<.0001**
Forest wet - Thicket wet	0.33547	0.0771	Inf	4.350	**0.0008**
Fynbos wet - Savanna wet	-0.58056	0.1420	Inf	-4.089	**0.0025**
Lucerne wet - Savanna wet	-0.60927	0.0960	Inf	-6.346	**<.0001**
Oil wet - Savanna wet	-0.87277	0.1410	Inf	-6.204	**<.0001**

Savanna wet - Thicket wet	0.44309	0.0687	Inf	6.452	**<.0001**

Chapter Five: General discussion

Overview

The influence of anthropogenic activities and seasonal fluctuations in baboon behaviour has not been investigated in some places (e.g. Baviaanskloof) and it has been underrepresented in some studies despite the problems that baboons pose in other parts of southern Africa. The two data chapters of this thesis (chapters three and four), give a thorough investigation of baboon spatial distribution and demographic variation across different landscape types in Baviaanskloof. Additionally, I explored the influence of different landscape types, seasons, and land use on the behaviour of the baboons. Overall, the results showed that the baboons in Baviaanskloof utilise agricultural lands and savanna more than other landscape types for their resources such as food, water, and roosting sites. These results show that the behaviour of baboons is influenced by seasonal fluctuations and differences in landscape types. This study contributes to raising awareness, increasing knowledge in the conservation and management of baboons and provides some ideas that could be implemented to promote coexistence between humans and wildlife. This is the first study to investigate and show how baboons are spatially distributed and how they behave across landscape types and seasons in Baviaanskloof.

Spatial distribution and demographic variation

Like in other places, the spatial distribution and population of baboons in Baviaanskloof have caused human-baboon conflict through crop raiding (Falls 1993; Strum 1994; Naughton-Treves et al. 1998; Hoffman & O'Riain 2010). By studying how baboons use space in Baviaanskloof, the findings of this study could help in understanding what areas attract baboons and if these areas are linked to human-baboon conflict. This research also sheds light on the behaviours baboons engage in and whether those behaviours cause conflict (for instance, feeding on agricultural land is a more significant problem than grooming). Additionally, this study could determine if there is seasonal variation in habitat use, which could intensify conflict. The results showed baboons' higher distribution and utilisation of agricultural lands and savanna landscape types. Baboons utilise agricultural lands and savanna landscape types for resources such as food, water, and sleeping sites. Given the problem that baboons pose in human-landscapes and the estimation of their population that is unknown in Baviaanskloof, future research is required because the issue of baboons in this area might escalate and reach a point where it threatens human health and safety. The utilisation of landscapes by baboons depends on the age and sex, with adults utilising risky areas and often raiding in human landscapes (Strum 2010), adult males are known as frequent raiders, and they are the most problematic (Fehlmann et al. 2017b).

Juveniles, infants, and adult females that have young occupy safe landscapes such as forests, and they usually do not partake in raiding to avoid putting their young life at risk.

Behaviour variation spatially and temporally

The main objective of chapter four was to investigate whether the behaviour of baboons varies seasonally, across landscape types and land use. The results bring to light that the behaviour of baboons is affected by seasons in such a way that they alter their behaviours to cope with different seasons. During the season of food scarcity, they venture on fallback foods such as leaves and grasses (Wrangham et al. 1998) and they change their foraging strategies by looking for readily available food that does not need more time to look for. These readily available foods are always found in human-landscapes such as agricultural lands in Baviaanskloof which causes human-baboon conflict. This study revealed that baboons feed most frequently in the forest, lucerne, savanna, and thicket during the wet season while they feed less in these landscape types during dry but more frequently in the lucerne. The results of this study demonstrate the alterations in baboon behaviour during different seasons.

Limitations

The current study did not conduct formal interviews with the community members and private farmers in Baviaanskloof to hear their perspectives on the issues of baboons, and how it affect them on a daily basis. Additionally, the study did not investigate the effect of seasonal fluctuations at the demographical level to see how different age groups and sexes deal with harsh environmental conditions, also the study used camera traps instead of direct observations, all this was due to time constraints.

The ecological behaviour of baboons is complex, thus, a long-term study is required to assess different aspects of their behaviour in more detail, to provide effective strategies to better manage them and their interactions with humans to avoid and/or minimise baboon-human conflict. This study serves as a basis to understand baboon behaviour at a natural/human-modified landscape level. Many studies have been conducted on baboon-human conflict in different places, and various management strategies have been raised and worked effectively, but the ability to accept and continue with the management strategies are context dependant. For instance, in some areas, these management strategies might be very expensive for the community members to adopt.

Future research

This study paved a way for future studies on Baviaanskloof baboon distribution and behaviour across different landscape types. Therefore, it can be used as a reference to assist in understanding the behaviour of baboons and how they navigate different landscapes that are found in this area. My results provide some insights into the conservation of wildlife and raises awareness into how the conversion of landscape types and seasonal changes alter the behaviour of baboons (at least in the Baviaanskloof).

Future research should thoroughly examine how different age groups and sexes utilise various landscape types in Baviaanskloof. This approach will provide a comprehensive understanding of baboon behaviour. Future studies should also examine seasonal fluctuations and landscape types at the demographic level to understand how different age groups of baboons respond to environmental factors. Future research could identify which age group is most affected by these factors. Baboons exhibit impressive behavioural flexibility, enabling them to adapt effectively to changing environmental conditions. Future studies could investigate the impact of seasonal changes and various landscape types on the physiology of baboon populations.

Conducting a comprehensive long-term study of baboon behaviour and ecology in the Baviaanskloof area and in southern Africa in general is crucial for the success of conservation initiatives. Understanding the social structures, foraging habits, and habitat requirements of these primates is vital, as a growing baboon population could greatly intensify the already complex issues they create in Baviaanskloof. Such research will provide valuable insights that can guide effective management strategies and foster a more balanced coexistence between baboons and the local ecosystem.

Conclusion

This study is among the few studies (i.e. Barton et al. 1992; Cowlishaw 1997; Hoffman & O'Riain 2010; Van Doorn 2010; Johnson et al. 2015; Chowdhury et al. 2020; Fehlmann et al. 2017b; Lewis & O'Riain 2017) that looked at the spatial distribution of baboons and the influence of seasonal fluctuations in the behaviour of baboons across different landscape types. I provided insights on the issues that baboons bring to the community when their population estimation and spatial distribution are not monitored. This study has suggested some management strategies that could be used to monitor baboons and address the issue of baboons in Baviaanskloof, but studies that will implement and put these management strategies into action are needed to see if these strategies are effective or not. This study showed that baboons alter their behaviour in trying to cope with seasonal factors by utilising human-modified environments and that exacerbate the human-baboon conflict in the area, therefore, these management strategies will assist in the coexistence of humans and wildlife. Baboons play a key role in the ecosystem since they help in dispersing seeds, create microhabitats, and aerate the soil (Tew et al. 2018), and this shows that they need to be conserved and monitored rather than being killed because humans consider them a nuisance in their environments.

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