SHORT COMMUNICATION

Diet of African wildcats in the unprotected southern Kalahari

Cindy Stadler[1],
Jessica Comley[2] ()[§] &
Dan M. Parker[2*] ()

[1]*Shamwari Private Game Reserve*

[2]*School of Biology and Environmental Sciences, University of Mpumalanga, Private Bag X11283, Mbombela, South Africa*

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INTRODUCTION

Over the last two centuries, global terrestrial carnivore populations have sharply declined, with factors such as geographic range contractions, fragmentation, and human persecution driving the extinction trend (Ripple *et al.*, 2014; Thorn, Scott, Green, Bateman & Cameron, 2009). The early 20th-century development in South Africa led to the disappearance of larger carnivores, but smaller ones like African wildcats (*Felis lybica cafra*) persisted (Skead, Boshoff, Kerley & Lloyd, 2007). Wildcats, considered 'least concern' by the IUCN, face poorly known population statuses, often estimated from incomplete data (Ghoddousi, Belbachir, Durant, Herbst & Rosen, 2022). Human–wildlife conflict, especially with livestock farmers in South Africa, poses a significant threat, leading to the culling of predators, including wildcats (Du Plessis *et al.*, 2018).

To comprehend a carnivore's role in an ecosystem, studying its diet is fundamental (Klare, Kamler, Stenkewitz & Macdonald, 2010). Diet analysis reveals feeding habits, potential prey, and behavioural insights. Wildcats, predominantly solitary foragers, pose challenges for data collection (Herbst & Mills, 2010), and existing knowledge on wildcat diet in southern Africa is based on protected areas, with murid rodents reported as primary prey (Herbst & Mills, 2010; Palmer & Fairall, 1988). However, wildcats, being opportunistic hunters, may vary their prey selection (Palmer & Fairall, 1988; Herbst & Mills, 2010). While various prey items have been recorded, detailed assessments outside protected areas are scarce (Greyling, Herbst & de Villiers, 2022). Our study aimed to investigate wildcat diets on livestock farms in the southern Kalahari, Northern Cape, South Africa, addressing potential human–wildcat conflicts, particularly with sheep, and enhancing our understanding of these carnivores' roles in arid ecosystems.

METHODS

Study area

The Kalahari ecosystem expands diagonally across southern to central Africa and consists of the largest continuous stretch of sand in the world (Van Rooyen & Van Rooyen, 1998). The southwestern Kalahari remains relatively unspoilt (Van Rooyen & Van Rooyen, 1998) and hosts the largest conservation area within the Kalahari ecosystem, the Kgalagadi Transfrontier Park (KTP), between South Africa and Botswana (Van Rooyen & Van Rooyen, 1998). Our study area fell within the broader southern Kalahari ecosystem and included livestock farms (n = 7), predominantly along the normally dry Molopo and Kuruman rivers, south of the KTP. Farms in the study area all raise sheep (*Ovis aries*) and/or goats (*Capra hircus*) and cattle (*Bos taurus*) and most also generate a financial income from game hunting in the winter season. Large and medium-sized antelope occur naturally in the region and include springbok (*Antidorcas marsupialis*), gemsbok (*Oryx gazella*), steenbok (*Raphicerus campestris*) and common duiker (*Sylvicapra grimmia*). Average annual rainfall is irregular and varies from 150 mm in the southwest to 350 mm in the northeastern part of the study area (Van Rooyen & Van Rooyen, 1998). Temperatures are also highly variable with maximum temperatures of 45°C or higher recorded in the summer and temperatures as low as –10.3°C recorded in the winter (Van Rooyen & Van Rooyen, 1998).

Methods

Wildcat stomach samples were collected opportunistically from livestock farmers (n = 7) across the study area between 2013 and 2017. In 2012, after several anecdotal conversations with farmers in the study area, it became clear to the authors that wildcats were routinely being culled in the region. Indeed, the culling of predators on livestock farms is a common practice across South Africa, to reduce livestock predation (Du Plessis *et al.*, 2018). In the Northern Cape province, farmers can legally cull wildcats, with a daily bag limit of

*To whom correspondence should be addressed.
E-mail: daniel.parker@ump.ac.za

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three individuals (Northern Cape Nature Conservation Act (9/2009), 2012). Since little data exist regarding wildcat diet outside protected areas, this scenario provided an opportunity to make use of potential diet data that would have otherwise been discarded and lost to science. Although we never expressly requested farmers to cull wildcats for the purposes of our study, when they learnt about the work from other farmers, several provided samples whenever they culled wildcats on their properties. Since the culling of wildcats was part of routine predator management on the farmers' properties and permitted under provincial law (Northern Cape Nature Conservation Act (9/2009), 2012), ethical clearance for the work was not required.

All wildcat stomachs were cut out, placed into a labelled zip lock bag and frozen by the farmer or farm manager, within 24 hours of the animal being culled. C.S. collected the frozen samples whenever contacted by any farmers in the area and noted the date the animal was culled, GPS coordinates of the farm, and the age and sex of the wildcat, if available.

Each frozen stomach sample was thawed and carefully washed and strained under running water and through a 1 mm mesh sieve to separate dietary remains (*e.g.*, hair, bones, and teeth) from other organic matter (Karanth & Sunquist, 1995). Dietary remains from each stomach were placed onto paper towel and allowed to air-dry for approximately 36 hours. Once dry, all dietary remains were placed into labelled plastic bags.

Cross-sections of mammalian hair found in the stomachs were prepared using the method proposed by Douglas (1989) and Reynolds & Aebischer (1991).

Hair samples were identified to species level by comparing the prepared slides to a hair reference collection ($n = 75$) of all potential mammalian prey species found in the study area (Karanth & Sunquist, 1995; Spaulding, Krausman & Ballard, 2000) including sheep. The presence of a species was recorded for each stomach sample in each year. If hair samples could not be classified to species level they were recorded as unidentified hair (Klare *et al.*, 2010). Given the high diversity of <300 g murid rodents in our study area (Skinner & Chimimba, 2005), and the inherent difficulty in identifying their remains to species level based on hair structure alone (Kamler *et al.*, 2021), all small (<300 g) murid rodents were classified as 'rodents' and not identified to species.

Statistical analyses

Vegetation remains (*e.g.* leaves, grass and seeds) in the stomachs were not included in further analyses as they were considered to be intentionally consumed to aid digestion and not for nutritional value (Vieira & Port, 2007) or incidentally consumed from the digestive tracts of mammalian prey (Herbst & Mills, 2010). Invertebrates were also not included in the analyses as their importance, in terms of overall biomass, in wildcat diet is considered negligible (Herbst & Mills, 2010). Unidentified hair was also excluded from further analyses (Bagchi & Mishra, 2006). However, for completeness, these broad categories are shown in Table 1.

The percentage occurrence (PO) of each food item (broad category or species) in each year was calculated as a measure of how frequently wildcats fed on each dietary component (Klare, Kamler & Macdonald, 2011). PO was calculated using the number of stomachs containing the food item as a function of the total number of stomachs. The importance of each food item found in the wildcat stomach samples in each year was then determined by calculating the relative frequency of occurrence (RFO) (Loveridge & Macdonald, 2003). RFO was calculated as a percentage using the number of times a specific food item was encountered as a function of the total number of occurrences of all food items found (Juarez & Marinho-Filho, 2002; Phillips, Winchell & Schmidt, 2007). RFO was calculated on a per stomach basis which allowed us to calculate the variability (standard deviation; S.D.) in the importance of the identified food items.

Using the RFO of the mammal species found in the wildcat stomach samples in each year, we assessed changes in yearly wildcat diet with non-metric multidimensional scaling (nMDS) and Bray-Curtis dissimilarities using the *vegan* package in R (Oksanen *et al.*, 2020). We tested for significant differences in diet across years in the nMDS ordination using permutational multivariate analysis of variance (PERMANOVA). We used the *envfit* function to plot species vectors on the ordination plots to identify the species in the diet driving the observed differences among years.

RESULTS

A total of 117 wildcat stomach samples were obtained for analysis between 2013 and 2017 (2013 = 33; 2014 = 31; 2015 = 1; 2016 = 15; 2017 = 37). However, 15 wildcat stomachs did not contain

Table 1. Diet of African wildcat (*Felis lybica cafra*) in the southern Kalahari, Northern Cape, South Africa, as determined by stomach content analyses and expressed as the percentage occurrence (PO) and relative frequency of occurrence (RFO). The standard deviations (S.D.) of the RFO values are also shown.

Food item	PO (%)		RFO (%)	
Mammal hair	90.2		39.1 ± 21.6	
Rodents		64.9		56.8 ± 45.3
Damaraland mole rat (*Fokumys damarensis*)		2.1		1.1 ± 7.3
Springhare (*Pedetes capensis*)		5.3		3.9 ± 18.3
Ground squirrel (*Xerus inauris*)		7.4		5.0 ± 19.5
Scrub hare (*Lepus saxatilis*)		1.1		0.5 ± 5.2
Suricate (*Suricata suricatta*)		6.4		3.6 ± 14.7
African wildcat (*Felis lybica cafra*)		21.3		18.6 ± 37.4
Sheep (*Ovis aries*)		13.8		10.4 ± 28.0
Other	3.9		0.9 ± 4.8	
Birds	26.5		8.9 ± 16.9	
Reptiles	2.0		0.4 ± 2.8	
Invertebrates	29.4		9.3 ± 15.3	
Vegetation remains	85.3		36.2 ± 22.1	
Unknown	15.7		5.1 ± 12.6	

any food items (2013 = 4; 2014 = 0; 2015 = 1; 2016 = 3; 2017 = 7). Thus, a final total of 102 stomachs (2013 = 29; 2014 = 31; 2015 = 0; 2016 = 12; 2017 = 30) was used to assess wildcat diet in our study area. The average number of food items per wildcat stomach was 2.6 ± 0.9 (S.D.) for 2013, 2.6 ± 1.0 for 2014, 2.4 ± 1.0 for 2016, and 2.6 ± 0.9 for 2017. Mammal hair (90.2%) and vegetative matter (85.3%) were the most frequently recorded food items in the wildcat stomachs (Table 1). Birds (26.5%) and reptiles (29.4%) were also recorded in approximately every third stomach (Table 1). Unknown food items were recorded in just less than 16% of all wildcat stomachs analysed (Table 1). Rodents (~65%) were the most frequently consumed mammal species, followed by sheep (13.8%), ground squirrels (*Xerus inauris*; 7.4%) and suricates (*Suricata suricatta*; 6.4%; Table 1). Wildcat hair was identified in 21.3% of all stomachs analysed (Table 1).

Mammal hair made up the greatest portion (RFO) of the diet of the wildcats across our study area (39.1%; Table 1). Vegetative matter was frequently recorded in wildcat stomachs (36.2%; Table 1). All other main food items contributed less than 10% to the diet of wildcats across our study area (Table 1). Like the PO results, rodents (~67%) were the most important food items in wildcat diet (Table 1). Wildcat hair was also a substantial component (18.6%) of the stomachs analysed (Table 1). Sheep contributed 10.4% of the diet of wildcats between 2013 and 2017 (Table 1).

Multidimensional scaling indicated that substantial overlap of the mammal species in the diet of wildcats existed across most years (Fig. 1). However, 2014 and 2017 were significantly different to the other years sampled (PERMANOVA pseudo$F_{3,92}$ = 6.35, $P < 0.001$). The significant differences in the mammal species consumed by wildcats in these years appear to have been driven by substantial decreases in the proportion of suricate and other rodent hair in the wildcat stomachs sampled (Fig. 1).

DISCUSSION

One of the crucial factors affecting the survival of carnivores in a specific habitat is food availability (Mills, 1990). Wildcats in our study had, on average, 2.5 food items present per stomach analysed and mammals (mostly rodents) dominated. Comparable results have been documented in the nearby KTP (Herbst & Mills, 2010) and the semi-arid Karoo National Park in central South Africa (Palmer & Fairall, 1988). The African wildcat's European cousin (*Felis silvestris silvestris*) shows a similar predilection for small, mostly murid, rodents across its range (Apostolico, Vercillo, La Porta & Ragni, 2016; Lozano, Moleón & Virgós, 2006; Malo, Lozano, Huertas & Virgós, 2004). However, when the availability of rodents declines or they are not available, European wildcats will broaden or shift their diets accordingly (Malo *et al.*, 2004). For example, Malo *et al.* (2004) demonstrated experimentally that when energetically more profitable rabbits (*Oryctolagus cuniculus*) were available to wildcats, they were targeted

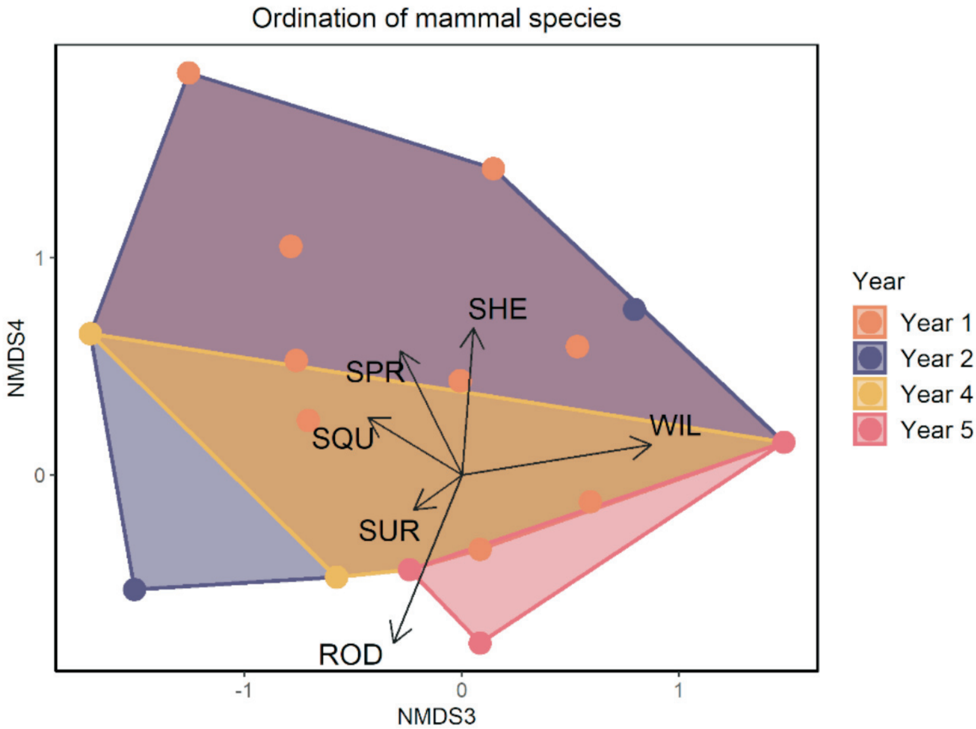

Fig. 1. The non-metric multidimensional scaling ordination of the proportions of the mammal species observed in the diet of African wildcats between 2013 and 2017 in the Kalahari. Stress = 0.04; ROD = Rodents; SUR = *Suricata suricatta*; SQU = *Xerus inauris*; SPR = *Pedetes capensis*; SHE = *Ovis aries*; WIL = *Felis lybica cafra*. Note: Year 3 (2015) is not shown since no wildcat stomachs were available for analysis in that year.

over rodents. These findings indicate that the European wildcat is likely a facultative specialist predator, depending on the availability of its prey (Malo *et al*., 2004).

The southern Kalahari is characterized by having low and irregular rainfall (Mills & Retief, 1984) which significantly impacts the quality and availability of the vegetation and, in turn, food availability for carnivores like wildcats (Herbst & Mills, 2010). Indeed, Herbst & Mills (2010) demonstrated that the availability of rodents and other wildcat prey species fluctuated significantly on both a seasonal and inter-annual basis. These seasonal and inter-annual changes in prey availability were reflected in the diet of the wildcats which they studied in the KTP (Herbst & Mills, 2010). As such, the authors suggested that KTP wildcats are adaptable small predators to counter the unpredictability of the system (Herbst & Mills, 2010). Although we did not assess the availability of wildcat prey during our study, we were able to demonstrate, like Herbst & Mills (2010), that wildcat diet changed significantly over the years of our study. These significant changes appeared to be driven by significant declines in the proportion of rodent species in the diet, presumably in response to decreased availability during those years. In 2015, less than 40 mm of rainfall was recorded on at least one farm in the study area (C. Stadler, pers. obs.). This lower-than-average rainfall may have contributed to significant declines in the rodent populations in the region, forcing wildcats to seek alternative prey (Malo *et al*., 2004; Herbst & Mills, 2010). It is possible that the lower rainfall during our study may also have contributed to the higher incidences of vegetative matter in the wildcat stomachs we analysed. However, as noted by Herbst & Mills (2010), plant matter often makes up a high percentage of wildcat scats, but direct observation of wildcats consuming plant material, which is low in calorific value, is generally rare. The high proportion of vegetative matter in scats, and presumably also stomachs, is believed to be due to incidental consumption from the digestive tracts of other prey items, or through intentional consumption to aid regurgitation of indigestible material such as fur (Herbst & Mills, 2010).

Several wildcat stomach samples from within our study area contained unidentified hair. Unidentifiable hair is not uncommon in carnivore diet assessments (Burgener & Gusset, 2003; Klare *et al.*, 2010, 2011). Often the cross-sections of hair samples are not clear enough to accurately identify, and this was likely the main reason for the relatively high occurrence of unidentifiable hair in some of our samples. Unidentifiable hair could also have been recorded because the mammal hair reference collection we used may not have covered all possible species present.

Our study is the first to document the consumption of sheep by the African wildcat. While the farmers in our study area maintain that wildcats actively hunt sheep lambs, we do not have any conclusive evidence for this contention. It is possible that wildcats in our study may have scavenged from sheep carcasses. However, a comprehensive assessment of wildcat diet in the nearby KTP, which included direct observations of several individuals, did not record any instances of scavenging from larger (>5 kg) carcasses amongst wildcats (Herbst & Mills, 2010). Nevertheless, European wildcats have been observed scavenging off roe deer (*Capreolus capreolus*) carcasses over successive days (Krofel, Južnič & Allen, 2021; Ruiz-Villar, López-Bao & Palomares, 2020), suggesting that additional research is required to ascertain the origin of the sheep remains in wildcat stomachs in our study area. Irrespective, the presence of sheep remains in wildcat stomachs in our study, albeit in relatively low proportions, has the potential to inflame human–wildcat conflict in the region, resulting in farmers opting to pre-emptively cull wildcats (Du Plessis *et al.*, 2018).

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§ORCID iDs

J. Comley orcid.org/0000-0002-3043-7022
D.M. Parker orcid.org/0000-0001-7555-5674

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