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Short Communication

Brown hyaena (*Parahyaena brunnea*) diet composition from Zingela Game Reserve, Limpopo Province, South Africa

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Brown hyaenas *Parahyaena brunnea* are classified as 'Near Threatened'. Although predominantly scavengers, they are frequently blamed for livestock depredations leading to persecution. Information on brown hyaena diets is important for understanding the degree of potential conflict with farming livelihoods and exploring diet variation across their range and how this might shift in response to land use change. Here we explore the diet of brown hyaena on a game reserve in the Limpopo Province, South Africa. We collected scats in 2013 (*n* = 55) and 2018 (*n* = 73) from Zingela Game Reserve to identify mammalian prey based on the cuticular scale imprints and cross-sectional appearance of hairs found in scat. Artiodactyls were most frequently consumed (total relative frequency of occurrence = 69.6%), dominated by common duiker *Sylvicapra grimmia* and steenbok *Raphicerus campestris*. Smaller prey were also common with Rodentia appearing in 15.8% of scats, although for all prey items there was some variation between years. We found only one occurrence of a domestic species in scats (donkey *Equus africanus*). Set alongside other studies from across southern Africa the results illustrate that brown hyaena are flexible in their diet and that domestic animals generally only represent a very small proportion of their diet.

Keywords: carnivore, human-carnivore conflict, human-wildlife conflict, predator, scat analysis

Introduction

Brown hyaenas *Parahyaena brunnea* are predominantly known as scavengers with an opportunistic feeding behaviour eating a variety of foods, including small to large mammals, birds, reptiles, invertebrates and fruit (Owens and Owens 1978, 1979; Mills 1990; Burgener and Gusset 2003; Kuhn et al. 2008; Van der Merwe et al. 2009; Slater and Muller 2014). To date, most data on brown hyaena diet composition has come from state-protected reserves or arid systems, such as the Kalahari (e.g. Mills and Mills 1978; Owens and Owens 1978), Namibian deserts (e.g. Skinner and van Aarde 1981; Kuhn et al. 2008; Wiesel 2010), and the Makgadikgadi National Park and neighbouring areas in Botswana (Maude and Mills 2005). More recently, dietary assessments have been reported from mesic systems, such as the Eastern Cape (Slater and Muller 2014; Comley et al. 2018) and Limpopo Province (Burgener and Gusset 2003; Williams et al. 2018) although the available data are still not representative of all habitats inhabited by brown hyaena across their geographic range. This study adds important information on brown hyaena diet for a population from a game reserve comprising predominantly sweet Bushveld and with access to neighbouring farming areas from Limpopo Province.

Previous studies of brown hyaena diet have shown it comprised mostly of gemsbok *Oryx gazella*, springbok *Antidorcas marsupialis* and springhare *Pedetes capensis* in the south and central Kalahari (Mills and Mills 1978; Owens and Owens 1978), Cape fur seal pups *Arctocephalus pusillus pusillus* along the Namib Desert coast (Skinner and van Aarde 1981; Siegfried 1984; Kuhn et al. 2008; Wiesel 2010), medium to large antelope, such as kudu *Tragelaphus strepsiceros* and red hartebeest *Alcelaphus caama* in the Eastern Cape (Slater and Muller 2014; Comley et al. 2018), large antelopes in North West Province (Yarnell et al. 2013; Van der Merwe et al. 2009), bushbuck *Tragelaphus scriptus* and red duiker *Cephalophus natalensis* in the Soutpansberg Mountains (Williams et al. 2018), and common duiker *Sylvicapra grimmia* from a game reserve in Limpopo Province (Burgener and Gusset 2003). Although indicating dietary variation across their range, none of these studies reported evidence to suggest that livestock can be considered an important food source of brown hyaena.

Nevertheless, poisoning, shooting and hunting of brown hyaenas frequently occur in Limpopo and North West provinces (St John et al. 2012; Thorn et al. 2012), owing

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to perceived and actual predation of livestock. Maude and Mills (2005) found that in the neighbouring farming areas adjacent the Makgadikgadi National Park, brown hyaenas were deriving significant dietary benefits from livestock carcasses. However, no evidence suggested that they hunted these domestic animals (Maude and Mills 2005). Williams et al. (2018) found a corrected frequency of occurrence of 7.2% of 137 brown hyaena scats contained livestock remains on private land in the Soutpansberg Mountains. Private lands are important refuges for brown hyaenas and represent a large proportion of their remaining range and are consequently critical to their conservation (Maude and Mills 2005; Kent and Hill 2013). Additional information on brown hyaena diets in areas adjacent to and within farming areas is needed to understand the origins of these conflicts. The objective of this study was to investigate brown hyaena diet composition on a game reserve surrounded by livestock farms in Limpopo Province, South Africa.

Methods

The study area, Zingela Game Reserve (ZGR; >25 000 ha), is located in the Capricorn district of Limpopo Province, South Africa (Figure 1). The vegetation is classified under Limpopo Sweet Bushveld of the savanna biome (Mucina and Rutherford 2006). The area experiences a summer rainfall with dry winters, a mean annual precipitation of approximately 421 mm and a mean annual temperature of 20.2 °C (December max.: 38.2 °C and June min.: 2.1 °C; Mucina and Rutherford 2006). The study area contains a large diversity of mammal species characteristic of southern African savanna systems, including carnivore species, e.g. leopard *Panthera pardus*, cheetah *Acinonyx jubatus*, black-backed jackal *Canis mesomelas*, and caracal *Caracal caracal*. Although the reserve had an electrified fence around the perimeter it was not predator proof and predators were able to cross between the reserve and adjacent farmlands.

We searched roads, game trails, and brown hyaena latrines for hyaena scats throughout 2013 and again in 2018. Brown hyaena scats were identified based on the size in combination with a conspicuous white or grey colouration (Hulsman et al. 2010). There was no evidence of resident spotted hyaenas *Crocuta crocuta* on the reserve during the study period, except for two isolated photographic records of adult spotted hyaenas across the 5-year period (Nico van der Merwe, pers. comm.). However, spotted hyaena scats are much larger than those of brown hyaena and accordingly we assumed all scats collected of a specific size and colour to be of brown hyaenas.

Scats were collected in paper bags labelled with collection number and the GPS position. Scats were air-dried and analysed following similar procedures to those described by Perrin and Campbell (1980), Buys and Keogh (1984) and Keogh (1979, 1983, 1985). Mammalian hair found in each scat sample was identified by cross-sectioning and creating scale imprints of hairs from each scat sample (Maude and Mills 2005). We selected from each scat sample a representative sample of hair comprising one hair for each size, thickness, colour, length, and shape (Maude and Mills 2005). Cuticular scale imprints were made on microscope slides by embedding the representative hairs in a thin layer clear nail varnish and then gently removing it when dry to reveal scale imprints. A cross-section was then prepared by taking a pipette filled with warm wax and inserting the hair inside and cutting through it after it had set. Scale imprints and cross-sections were then photographed for identification purposes. Known hair samples were obtained from the Amathole Museum and used to create our own reference collection of hair cuticular scale imprints and cross-sectional appearances for all the possible mammal species from the study area. Mammalian dietary items were identified to the lowest possible taxonomic level by comparing cuticular scale imprint patterns along with the size and shape of the medulla and cortex of hairs from their cross-sections with those of our hair reference collection or published hair keys (Perrin and Campbell 1980; Keogh 1979, 1983, 1985; Buys and Keogh 1984; Taru and Backwell 2014). Where inconsistencies existed, we prioritised categorisations based on our reference collection, because it had been prepared in exactly the same manner as our samples.

We ascertained that an asymptote had been reached by plotting the cumulative dietary diversity (H) against the number of scats analysed (*k*) in order to determine whether brown hyaena diet had been sampled adequately (Glen and Dickman 2006). Dietary diversity of food items was calculated using the Brillouin index:

$$H_k = \frac{\ln N! - \sum \ln n_i!}{N}$$

where H_k represents the diversity, N the recorded total number of individual prey, and n_i the number of prey items of a specific individual within the ith category (Brillouin 1956). To obtain values for the cumulative dietary diversity, we calculated the Brillouin diversity index for the first scat's food items, then added the food items from the next scat, recalculated the diversity, and repeated the process until all scats were added. The Brillouin index was chosen because of the randomness of our sample collection (Magurran 2004). Frequency of prey occurrence (% FO) in the scats was calculated as a measure of how frequently brown hyaenas fed on each food item using the formula $n_x/n_{total} \times 100$, where n_x is the number of scats that contained a specific food item and n_{total} is the total number of scats (Burgener and Gusset 2003; Loveridge and Macdonald 2003; Van der Merwe et al. 2009; Slater and Muller 2014). A relative frequency of occurrence (% RF) was then calculated as a measure of the importance of each food item to its overall diet based on $n_0/n_1 \times 100$, where n_0 is the number of occurrences of a specific food type in scats and n_1 is the total number of occurrences of all the food types in scats (Burgener and Gusset 2003; Loveridge and Macdonald 2003; Van der Merwe et al. 2009; Slater and Muller 2014). We investigated the dietary composition from collected samples for 2013 and 2018, as well as all scats together.

Results

We analysed 55 scats from 2013 and 73 scats from 2018 (n = 128), with an asymptote in the plot of Brillouin's index

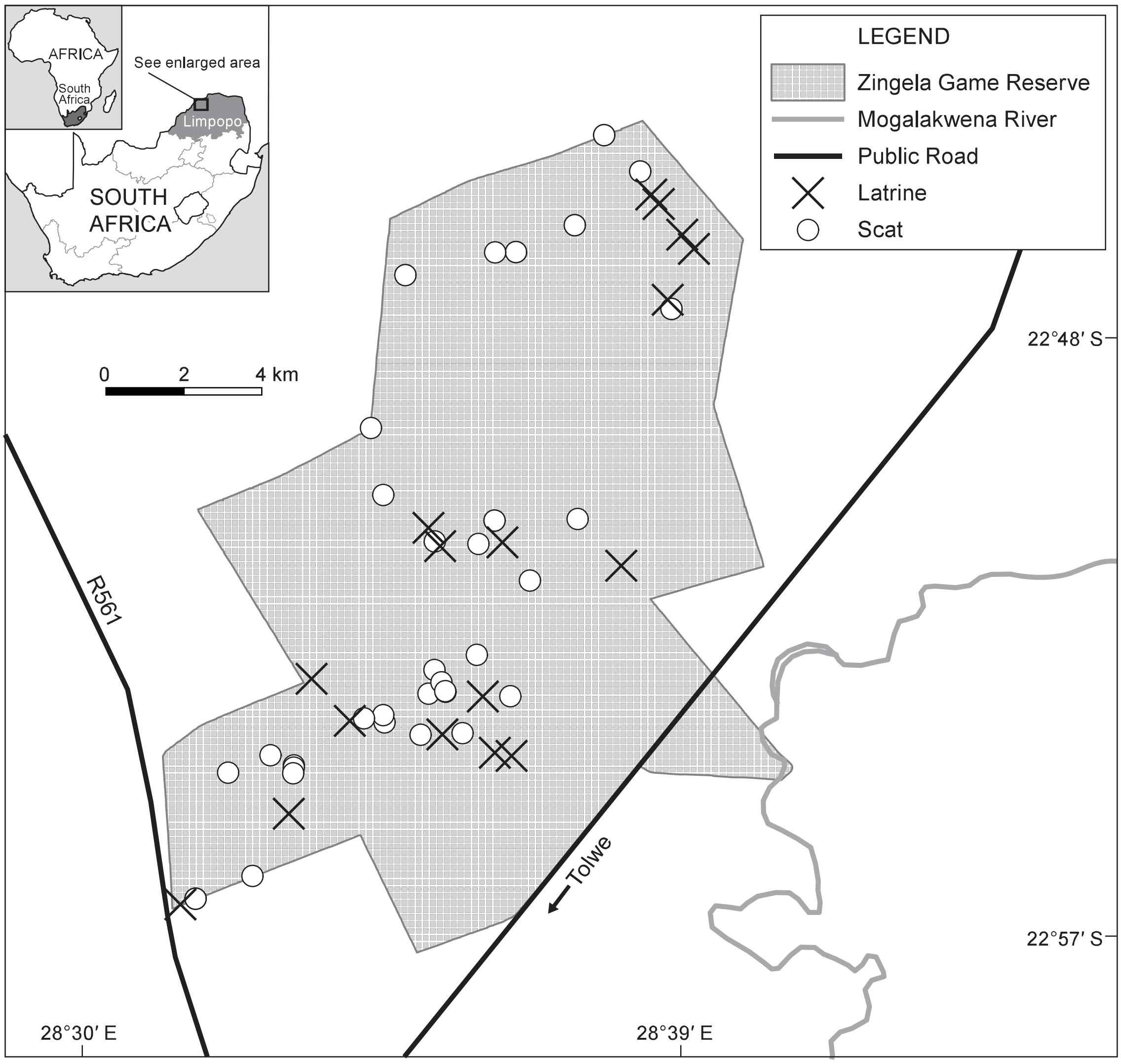

Figure 1: Map of Zingela Game Reserve within Limpopo Province illustrating scat collection locations from known latrines and individually along roads and trails

suggesting that the diet was adequately sampled using the combined sample of scats (Magurran 2004) (Figure 2). We collected 76% (*n* = 42 of 55 scats) of scats from 8 latrines in 2013, 56% (*n* = 41 of 73 scats) were collected from 11 latrines in 2018 and the rest were collected from roads and trails. Though a few latrines were close to each other and could potentially represent the same individual, most were distributed far from each other (range = 0.31–21.77 km, mean = 8.63 km, SE = 0.46 km) and we accordingly assumed they were representative of multiple individuals (Figure 1).

In total, we found 32 different mammal species in the scat samples (23 for 2013 and 27 for 2018; Table 1) with a mean of 1.17 mammal species per scat (SD = 0.42; SE = 0.06). Artiodactyls (69.6% RF; 101 of 145 recorded food items within 128 scats) followed by Rodentia (15.8% RF; 23 of 145 recorded food items) had the highest relative frequency of occurrence, whereas plant material was found in 23 scats (18%) and an additional 21 scats (16%) contained insect remains. Large mammals (>10 kg) made up 81.2% of the total number of food items. Three percent of the scats contained brown hyaena hair (*n* = 4 of 128). We found bird feathers in 14 of the scats (11%) collected and tortoise remains in 4 scats (3%). As a result of the insufficient bird and reptile remains obtained from scats, identification to species level was not possible and consequently we did not include these in our calculation of the relative frequency of occurrence.

Common duiker remains had the highest occurrence in scats (total: 17.9 ± 0.2% RF), followed by steenbok *Raphicerus campestris* (total: 10.3 ± 0.2% RF), kudu (total: 6.9 ± 0.2% RF), and bushbuck (total: 6.2 ± 0.2% RF) (Table 1). Impala *Aepyceros melampus* remains were found in 8 scats (total: 5.5 ± 0.2% RF). Blue wildebeest *Connochaetes taurinus,* scrub hare *Lepus saxatilis* and porcupine *Hystrix africaeaustralis* remains were found in 6 scats each (total: 4.1 ± 0.2% RF each). We found no remains of domesticated animals other than one scat from 2013 containing donkey

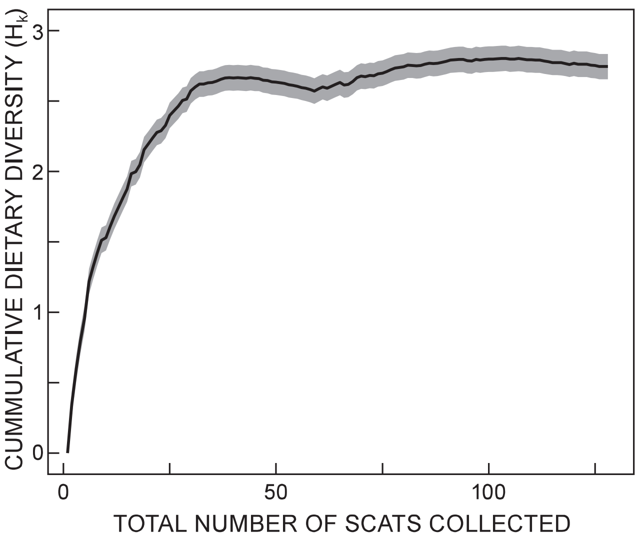

Figure 2: Species accumulation curve based on the cumulative Brillouin index for all scat samples from Zingela Game Reserve. Shaded area represents the 95% confidence intervals

Equus africanus hair remains.

Discussion

Brown hyaena diets vary across their geographic range (Mills and Mills 1978; Maude and Mills 2005; Wiesel 2010; Slater and Muller 2014; Comley et al. 2018; Williams et al. 2018). Similar to Burgener and Gussett (2003) and Slater and Muller (2014) the diet of brown hyaenas at ZGR had a high frequency of occurrence of antelope more than 10 kg. The five most common recorded brown hyaena food items at ZGR, common duiker, steenbok, kudu, bushbuck, and impala (totalling 46.9% RF), reflect the preferred prey species of both leopards and cheetah (Skinner and Chimimba 2005; Hayward et al. 2006a, 2006b; Balme et al. 2007; Chase Grey et al. 2017; Williams et al. 2018) and could therefore be a reflection of their dependence on scavenging and kleptoparasitism opportunities provided by other carnivores (Yarnell et al. 2013). Brown hyaenas have a low hunting success (4.7%; Maude and Mills 2005) and it has been suggested that they are dependent on large predators for scavenging opportunities (Stein et al. 2013; Yarnell et al. 2013; Williams et al. 2018). Brown hyaena have been recorded stealing kills from cheetah (Owens and Owens 1978), leopard, and caracal *Caracal caracal* (Mills 1990). The diet at ZGR therefore appears characteristic of brown hyaenas scavenging from the kills of other carnivores. Brown hyaena hair found in scat was most likely attributable to auto- or allogrooming (Owens and Owens 1978) and does not necessarily suggest cannibalism.

Only 8% (*n* = 10 of 128 scats) of the scats analysed contained seeds from *Grewia* spp., which is lower than that reported for the southern and central Kalahari (Mills and Mills 1978; Owens and Owens 1978). In arid environments like the Kalahari, brown hyaenas supplement their diet with fruits, such as wild melons, cucumbers and berries from the *Grewia* shrub (Mills and Mills 1978; Owens and Owens 1978). Because ZGR has plenty of permanent artificial water sources available, as well as other large predators providing sufficient carrion, brown hyaenas are capable of getting sufficient water, which likely explains the low amount of seeds found in scats. Although three scats contained almost exclusively grass with very few hairs present, grass found within two of the scats was finely broken up, suggesting that it might be secondary prey from the stomach remains of the primary prey (Trites and Joy 2005).

Brown hyaenas are classified as 'Near Threatened' by the IUCN Red List and consequently consideration should be allocated to the management of these animals (Wiesel 2015). However, hyaena-human conflict is a considerable problem in many areas of southern Africa and many farmers blame the disappearance of livestock on brown hyaenas (Maude 2005; Maude and Mills 2005; Schiess-Meier et al. 2007; Van As 2012; Thorn et al. 2013; Weise et al. 2015). Although the areas surrounding the study site intensively farm with cattle *Bos taurus* and goats *Capra aegagrus hircus*, there was little evidence to suggest that brown hyaenas were feeding on livestock in the study area. Brown hyaenas from ZGR are able to cross fences to these neighbouring areas and consequently dietary remains found in the sample does not necessarily originate from ZGR. Donkey hair remains were found in one scat from 2013 indicating that at least one of the hyaenas had left the reserve since there are no domestic species on ZGR. It is conceivable, however, that further analysis using scats collected from neighbouring farming areas could provide alternative evidence. Various farmers near ZGR and in Limpopo Province have reported livestock losses from brown hyaenas (Faure and Hill, unpublished data), which on current evidence suggests perceptions of losses to hyaenas exceed estimates from the dietary analysis. Conflict between brown hyaenas and humans can be reduced by overcoming the mismatch between actual versus perceived threats through landowner education and improved response by government officials and conservation practitioners to livestock predation reports (Chase Grey et al. 2017). Given our results suggesting that brown hyaenas rely mostly on natural prey species, we advocate the necessity for increased community engagement efforts to create awareness of the valuable roles scavengers and other carnivores play within ecosystems in order to increase tolerance of brown hyaenas (Mills and Hofer 1998).

Conclusions

The brown hyaena is frequently blamed for livestock depredations across its geographic range. Our results, from a private reserve bordering a livestock farming area, found only a single domestic animal in 128 brown hyaena scats despite the brown hyaenas being able to cross the fence and leave the reserve. Instead, Artiodactyl species constituted a relative frequency of occurrence of 69.6%, with the top five most frequent food items reflecting the preferred prey of leopard and cheetah and 81.2% of food items comprising large mammals (>10 kg). Our study contributes to the current understanding of the feeding ecology and dietary composition of brown hyaenas from the Limpopo Province, South Africa. We advocate the

Table 1: Food items recorded in brown hyaena (*Parahyaena brunnea*) scats collected in 2013 (*n* = 55) and 2018 (*n* = 73) from Zingela Game Reserve in Limpopo Province, South Africa.

Food Item	%FO (2013)	%FO (2018)	%RF (2013)	%RF (2018)	TOTAL %RF
Artiodactyla					
Blesbok *Damaliscus phillipsi* (*n* = 2)	3.6 ± 0.39	0	3.4 ± 0.34	0	1.4 ± 0.2
Blue Wildebeest *Connochaetes taurinus* (*n* = 6)	1.8 ± 0.39	6.8 ± 0.31	1.7 ± 0.34	5.7 ± 0.25	4.1 ± 0.2
Bushbuck *Tragelaphus scriptus* (*n* = 9)	1.8 ± 0.39	11 ± 0.31	1.7 ± 0.34	9.2 ± 0.25	6.2 ± 0.2
Common Duiker *Sylvicapra grimmia* (*n* = 26)	20 ± 0.39	20.5 ± 0.31	19 ± 0.34	17.2 ± 0.25	17.9 ± 0.2
Common Warthog *Phacochoerus africanus* (*n* = 3)	1.8 ± 0.39	2.7 ± 0.31	1.7 ± 0.34	2.3 ± 0.25	2.1 ± 0.2
Eland *Taurotragus oryx* (*n* = 2)	1.8 ± 0.39	1.4 ± 0.31	1.7 ± 0.34	1.1 ± 0.25	1.4 ± 0.2
Gemsbok *Oryx gazella* (*n* = 3)	1.8 ± 0.39	2.7 ± 0.31	1.7 ± 0.34	2.3 ± 0.25	2.1 ± 0.2
Giraffe *Giraffa giraffa* (*n* = 1)	0	1.4 ± 0.31	0	1.1 ± 0.25	0.7 ± 0.2
Greater Kudu *Tragelaphus strepsiceros* (*n* = 10)	12.7 ± 0.39	4.1 ± 0.31	12.1 ± 0.34	3.4 ± 0.25	6.9 ± 0.2
Impala *Aepyceros melampus* (*n* = 8)	3.6 ± 0.39	8.2 ± 0.31	3.4 ± 0.34	6.9 ± 0.25	5.5 ± 0.2
Nyala *Tragelaphus angasii* (*n* = 3)	1.8 ± 0.39	2.7 ± 0.31	1.7 ± 0.34	2.3 ± 0.25	2.1 ± 0.2
Red Hartebeest *Alcelaphus caama* (n = 5)	1.8 ± 0.39	5.5 ± 0.31	1.7 ± 0.34	4.6 ± 0.25	3.4 ± 0.2
Roan *Hippotragus equinus* (*n* = 1)	0	1.4 ± 0.31	0	1.1 ± 0.25	0.7 ± 0.2
Sable *Hippotragus niger* (*n* = 2)	1.8 ± 0.39	1.4 ± 0.31	1.7 ± 0.34	1.1 ± 0.25	1.4 ± 0.2
Steenbok *Raphicerus campestris* (*n* = 15)	12.7 ± 0.39	11 ± 0.31	12.1 ± 0.34	9.2 ± 0.25	10.3 ± 0.2
Waterbuck *Kobus ellipsiprymnus* (*n* = 5)	3.6 ± 0.39	4.1 ± 0.31	3.4 ± 0.34	3.4 ± 0.25	3.4 ± 0.2
Perissodactyla					
Burchell's Zebra *Equus quagga burchellii* (*n* = 5)	3.6 ± 0.39	4.1 ± 0.31	3.4 ± 0.34	3.4 ± 0.25	3.4 ± 0.2
Donkey *Equus africanus* (*n* = 1)	1.8 ± 0.39	0	1.7 ± 0.34	0	0.7 ± 0.2
Carnivora					
Aardwolf *Proteles cristata* (*n* = 1)	0	1.4 ± 0.31	0	1.1 ± 0.25	0.7 ± 0.2
Banded Mongoose *Mungos mungo* (*n* = 1)	0	1.4 ± 0.31	0	1.1 ± 0.25	0.7 ± 0.2
Bat-Eared fox *Otocyon megalotis* (*n* = 1)	1.8 ± 0.39	0	1.7 ± 0.34	0	0.7 ± 0.2
Black-Backed Jackal *Canis mesomelas* (*n* = 2)	0	2.7 ± 0.31	0	2.3 ± 0.25	1.4 ± 0.2
Brown Hyena *Parahyaena brunnea* (*n* = 4)	0	5.5 ± 0.31	0	4.6 ± 0.25	2.8 ± 0.2
Slender Mongoose *Herpestes sanguineus* (*n* = 1)	0	1.4 ± 0.31	0	1.1 ± 0.25	0.7 ± 0.2
Yellow Mongoose *Cynictis penicillata* (*n* = 1)	1.8 ± 0.39	0	1.7 ± 0.34	0	0.7 ± 0.2
Primates					
Chacma Baboon *Papio ursinus* (*n* = 1)	0	1.4 ± 0.31	0	1.1 ± 0.25	0.7 ± 0.2
Vervet Monkey *Chlorocebus pygerythrus* (*n* = 3)	1.8 ± 0.39	2.7 ± 0.31	1.7 ± 0.34	2.3 ± 0.25	2.1 ± 0.2
Rodentia					
African Dormouse *Graphiurus murinus* (*n* = 3)	0	4.1 ± 0.31	0	3.4 ± 0.25	2.1 ± 0.2
Porcupine *Hystrix africaeaustralis (n* = 6)	*10.9 ± 0.39*	*0*	*10.3 ± 0.34*	*0*	*4.1 ± 0.2*
Pouched Mouse *Saccostomus campestris* (*n* = 3)	*1.8 ± 0.39*	*2.7 ± 0.31*	*1.7 ± 0.34*	*2.3 ± 0.25*	*2.1 ± 0.2*
Scrub Hare *Lepus saxatilis* (*n* = 6)	*5.5 ± 0.39*	*4.1 ± 0.31*	*5.2 ± 0.34*	*3.4 ± 0.25*	*4.1 ± 0.2*
Spring Hare *Pedetes capensis* (*n* = 5)	5.5 ± 0.39	2.7 ± 0.31	5.2 ± 0.34	2.3 ± 0.25	3.4 ± 0.2

%FO = Percentage frequency of occurrence. %RF = Percentage relative frequency of occurrence.

necessity for additional dietary studies to compare scats from within livestock farming areas to neighbouring game reserve areas.

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