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# Seasonal diet and numbers of prey consumed by Cape foxes *Vulpes chama* in South Africa

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The Cape fox *Vulpes chama* is one of the least studied *Vulpes* species, and little is known about their diet. By analyzing contents of scats, we determined the seasonal diet of Cape foxes on Benfontein Game Farm (BGF) in South Africa, and determined the biomass and number of rodents consumed. We also determined the diet of Cape foxes on a nearby private livestock ranch (PR) in winter when sheep were lambing. On BGF, murids were the dominant food item, and comprised 44–90% of the biomass consumed across seasons. Other major food items that were seasonally important were leporids and berries. Although arthropods were frequently consumed, they were negligible in terms of biomass consumed. On PR, sheep were found in 19% of scats, but in relatively low amounts per scat, indicating sheep were likely scavenged rather than predated upon. On BGF, the estimated annual consumption was 3,861 rodent/fox, or about 11 rodent/day/fox. Our results indicate Cape foxes feed primarily on small rodents, and therefore Cape foxes might be beneficial to livestock and game farm owners in southern Africa.

Compared to other carnivores, canids often come into conflict with humans, usually via predation on domestic animals and game species (Sillero-Zubiri et al. 2004). Although *Canis* species are often targeted due to livestock predation, smaller *Vulpes* species such as red foxes (*V. vulpes*) are sometimes heavily persecuted due to their real or perceived predation on game and livestock, usually sheep lambs (Sillero-Zubiri et al. 2004). Information on the consumption of livestock and game by other *Vulpes* species is poorly known, mostly due to lack of detailed dietary studies. Similarly, data on the biomass of rodents consumed by small *Vulpes* species is unknown, although such information could demonstrate whether *Vulpes* species have the potential to suppress rodent populations, thereby helping sheep and game farm managers.

In South Africa, Cape foxes *Vulpes chama* often are considered a problem animal in sheep farming areas due to their perceived predation on lambs, and consequently thousands are killed in control operations on an annual basis (Stuart and Stuart 2004). Although Cape foxes have been documented to kill lambs (Stuart 1981, Bester 1982), the level of predation is uncertain, as much of the consumption may be from carrion (Stuart and Stuart 2004, Skinner and Chimimba 2005). Clearly, more information is needed on Cape fox diets from sheep farms, as this will lead to a better understanding of the importance of sheep in the diet of this small (2–3 kg) but controversial carnivore.

The Cape fox has been little studied, and the only available data on their diets come from relatively few studies

( $n = 6$ ) that examined stomach contents of Cape foxes killed over several years in control operations carried out across large regions (Bothma 1971, Smithers 1971, Lynch 1975, Stuart 1981, Bester 1982, Kok 1996). Those studies showed that diets of Cape foxes were dominated by small rodents (38–74% of stomachs across studies) and insects (30–61%), followed by livestock, including carrion (0–32%), reptiles (1–30%), and birds (4–26%). However, it is unknown if and how the Cape fox diet changes across seasons. Also, the number of small rodents consumed by Cape foxes has never been estimated, although such information would help determine the impact of Cape foxes on rodent communities.

To better understand Cape fox diets, we analyzed their scats collected from a private game farm in South Africa. Our objectives were to compare the diet of Cape foxes among seasons, and to estimate the number of small mammals consumed per year. We also examined the winter diet of Cape foxes on a nearby sheep farm to determine the importance of sheep in the fox diet during the lambing season.

## Material and methods

This paper was part of a larger study investigating the ecology of Cape foxes and other canid species across two study sites in South Africa (Kamler et al. 2012b, 2013, Kamler and Macdonald 2014). Site 1 was Benfontein Game Farm (BGF; 110 km<sup>2</sup>; 28°53'S, 24°49'E), which was

situated on the border of the Northern Cape and Free State provinces and located 8 km southeast of Kimberley. Site 2 was private ranches (PR; 81 km<sup>2</sup>; 28°59'S, 24°48'E) located 5 km south of BGF in the Free State Province. Detailed descriptions of the study sites, habitat, and species present are given in previous papers (Kamler et al. 2012b, 2013). In summary, BGF is managed primarily for wild ungulates, including springbok *Antidorcas marsupialis*, blesbok *Damaliscus dorcas* and black wildebeest *Connochaetes gnou*, along with some domestic cattle *Bos taurus*. The PR is managed primarily for domestic sheep, with some wild ungulates, including springbok, blesbok and oryx *Oryx gazella*. Other carnivores present on the study sites included black-backed jackals *Canis mesomelas*, bat-eared foxes *Otocyon megalotis*, aardwolves *Proteles cristatus*, caracals *Caracal caracal*, African wild cats *Felis silvestris*, black-footed cats *F. nigripes*, striped polecats *Ictonyx striatus*, small-spotted genets *Genetta genetta* and at least five species of Herpestidae. The dominant vegetation type on both sites was Eastern Mixed Nama Karoo, along with lesser amounts of Kimberley Thorn Bushveld (Mucina and Rutherford 2006).

Scats were collected from June 2005 through September 2007, primarily by searching the trails and areas surrounding the den and resting sites of radio-collared Cape foxes on BGF (n = 11) and PR (n = 8). We were confident all scats used in analysis were from Cape foxes because scats were only collected near Cape fox dens, and their shape and relatively small size were unique compared to scats of other sympatric carnivores (Chame 2003). To evaluate seasonal differences in the diet on BGF, the scats were divided into spring (Sep–Nov), autumn (Mar–May), and winter (Jun–Aug). Too few scats (n < 15) were collected in summer (Dec–Feb), thus this season was omitted from analyses. On PR, scats were collected primarily in winter to determine diets during the sheep lambing period.

To remove the unidentifiable micro-fraction from the faeces, we placed single scats in pieces of nylon stockings tied at both ends. After soaking these bags in warm water for > 30 min, they were washed in an automatic washing machine with laundry detergent (Kamler et al. 2007). After the scats had air dried, the bags were cut open and the contents were weighed. The remains then were microscopically determined using the following taxonomic–ecological categories modified from Jędrzejewska and Jędrzejewski (1998): (I) arthropods, (II) reptiles, (III) birds, (IV) shrews (Soricidae), (V) rodents weighing ≤ 50 g, (VI) rodents weighing 51–150g, (VII) mole rats *Cryptomys hottentotus*, (VIII) ground squirrels *Xerus inauris*, (IX) leporids *Lepus capensis* and *L. saxatilis* and springhares *Pedetes capensis*, (X) porcupines *Hystrix africaeaustralis*, (XI) ungulates, (XII) unidentified mammals, (XIII) grass, (XIV) berries and (XV) inorganic non-food items (e.g. gravel). Seeds, insects and mammalian remains were further identified to the finest taxonomic level possible. Mammalian teeth were classified to species based on available literature (de Graaff 1981) and by comparison with reference material obtained from the McGregor Museum, Kimberley. Hairs were identified by their microstructure according to Keogh (1985) using negative imprints that were prepared by placing single hairs on slides that were thinly covered with transparent nail polish (Klare et al. 2010). The percentage volume of each

prey category in the scat was estimated visually to the nearest 5%. Items that contributed < 5% to the whole scat were noted as trace. Non-food items were excluded from further analysis.

As scat analysis is an indirect way to assess the diet of carnivores and is dependent on the method used (Klare et al. 2011a), results were presented using three different methods. The preferred way of presenting dietary data should be the amount of ingested biomass as this is ecologically the most relevant parameter (Klare et al. 2011a). As no biomass calculation models are available for the Cape fox, we chose the model developed by Goszczyński (1974). This method uses correction factors developed for red foxes *Vulpes vulpes*, a closely related species with a similar prey spectrum, and therefore should be applicable to the Cape fox. To allow comparisons to other studies, we also calculated the frequency of occurrence of the different prey categories (i.e. percentage of scats containing at least traces of a food category), as well as percent volume (i.e. percentage of the total volume of a given prey category compared to the total volume of all food items).

To test between seasons and study sites for significant differences in their percentile dietary composition (i.e. the shares of all 14 food categories based on ingested biomass) a Monte Carlo Permutation with 9999 permutations was performed with the computer program Canoco 4.5 (Canepuccia et al. 2007). The unimodal model canonical correspondence analysis was used as this method is independent of data distribution and also is little affected by large number of zeros in the data set (Ter Braak and Šmilauer 2002). To test for significant differences in only one prey category, the nonparametric Mann–Whitney U-test was used for biomass data, whereas  $\chi^2$  contingency tables were used for frequency of occurrence data (both tests performed with SPSS ver. 14.0).

Number of small mammals consumed was calculated according to formula modified from Jędrzejewska and Jędrzejewski (1998):  $N_{\text{prey}} = (\text{DFI} \times B_{\text{prey}} \times n_{\text{days}} \times 100) / \text{BM}_{\text{prey}}$ , where  $N_{\text{prey}}$  is the number of prey individuals eaten by each Cape fox, DFI the daily food intake,  $B_{\text{prey}}$  the fraction of a given prey in biomass ingested by Cape foxes,  $n_{\text{days}}$  the number of days per season, and  $\text{BM}_{\text{prey}}$  the mean body mass of prey. The daily food intake for Cape foxes was assumed, conservatively, to be 250 g because carnivores are assumed to consume food equaling 7–10% of their body mass per day (Mukherjee et al. 2004). Mean body mass of prey species was taken from Stuart and Stuart (2001). If a range of body mass was given, or body mass of males and females differed, we used the mean of the given values. A body mass of 40 g was used for unidentified rodents.

## Results

In spring, the diet of Cape foxes on BGF was clearly dominated by rodents weighing ≤ 50 g (71% of the ingested biomass; Table 1). The gerbil mouse *Malacothrix typica* was the most important prey species, as it occurred in nearly half of all scats, and constituted at least 43% of the ingested biomass (and probably more, as 14% of biomass was unidentified Dendromurinae). The pygmy mouse *Mus minutoides*

Table 1. Seasonal diet of Capes foxes *Vulpes chama* on Benfontein Game Farm and a private ranch, South Africa, 2005–2007, expressed as percentage of ingested biomass (Biomass), percentage of total scat volume (Vol), and frequency of occurrence in all scats (Occ); n = number of scats analyzed.

	Benfontein Game Farm															
	Spring (n = 44)				Autumn (n = 37)				Winter (n = 49)				Private ranch Winter (n = 26)			
	Biomass [%]	Vol [%]	Occ [%]	Biomass [%]	Vol [%]	Occ [%]	Biomass [%]	Vol [%]	Occ [%]	Biomass [%]	Vol [%]	Occ [%]	Biomass [%]	Vol [%]	Occ [%]	
<b>Arthropod</b>	<b>1.5</b>	<b>5.2</b>	<b>72.7</b>	<b>0.5</b>	<b>2.6</b>	<b>81.1</b>	<b>0.2</b>	<b>0.4</b>	<b>51.0</b>	<b>0.2</b>	<b>0.4</b>	<b>0.2</b>	<b>0.4</b>	<b>0.4</b>	<b>34.6</b>	
Northern harvester termite <i>Hodotermes mossambicus</i>	0.1	0.2	65.9	0.3	1.6	54.1	0.0	0.2	24.5	0.0	0.0	0.0	0.0	0.0	19.2	
Beetle (Coleoptera)	0.7	3.0	34.1	0.1	0.3	43.2	0.0	0.0	16.3	0.0	0.0	0.0	0.0	0.0	11.5	
Grasshopper (Orthoptera)	0.0	0.0	6.8	0.1	0.6	18.9	0.1	0.1	12.2	0.2	0.4	0.0	0.0	0.0	15.4	
Scorpion (Scorpiones)	0.7	2.0	22.7	0.0	0.0	2.7	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	
Other <sup>a</sup>	0.0	0.0	18.2	0.1	21.6	0.1	0.1	12.2	0.0	0.0	0.0	0.0	0.0	0.0	7.7	
<b>Reptile</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>5.4</b>	<b>0.0</b>	<b>0.0</b>	<b>4.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	
<b>Bird</b>	<b>1.1</b>	<b>1.0</b>	<b>22.7</b>	<b>3.2</b>	<b>3.5</b>	<b>29.8</b>	<b>6.5</b>	<b>6.0</b>	<b>24.5</b>	<b>4.0</b>	<b>6.0</b>	<b>15.4</b>	<b>4.0</b>	<b>6.0</b>	<b>15.4</b>	
<b>Mammal</b>	<b>96.8</b>	<b>90.5</b>	<b>100</b>	<b>92.9</b>	<b>82.6</b>	<b>100</b>	<b>61.6</b>	<b>77.4</b>	<b>98.0</b>	<b>81.7</b>	<b>76.5</b>	<b>96.2</b>	<b>81.7</b>	<b>76.5</b>	<b>96.2</b>	
Shrew <sup>b</sup>	0.7	0.9	11.4	1.6	1.4	16.2	0.2	0.3	4.0	0.5	0.6	11.5	0.5	0.6	11.5	
Rodents weighing ≤ 50 g	70.9	64.8	88.6	33.3	33.6	62.2	30.8	51.7	69.4	38.4	37.4	65.4	38.4	37.4	65.4	
Pygmy mouse <i>Mus minotooides</i>	7.9	8.9	47.7	12.8	14.0	40.5	2.5	3.1	32.7	13.7	15.9	42.3	13.7	15.9	42.3	
Gerbil mouse <i>Malacothrix typica</i>	42.7	34.4	47.7	6.0	5.5	16.2	8.7	9.4	20.4	7.2	3.6	11.5	7.2	3.6	11.5	
Gray climbing mouse <i>Dendromus melanotis</i>	5.4	6.2	13.6	6.0	4.2	10.8	4.4	9.4	14.3	0.0	0.0	0.0	0.0	0.0	0.0	
Unidentified Dendromurinae ( <i>Malacothrix/ Dendromus</i> )	13.6	1.8	29.5	8.5	9.9	24.3	13.3	28.6	35.7	16.8	17.3	23.1	16.8	17.3	23.1	
Other <sup>c</sup>	1.3	1.4	9.1	0.0	0.0	0.0	2.1	1.3	10.2	0.7	0.6	7.7	0.7	0.6	7.7	
Rodents weighing 51–150 g	19.2	21.1	43.2	30.2	36.4	59.5	12.8	15.5	32.7	22.8	28.6	50.0	22.8	28.6	50.0	
Bushveld gerbil <i>Tatera leucogaster</i>	16.9	18.2	31.8	19.2	19.2	29.7	9.3	10.7	20.4	4.7	4.6	11.5	4.7	4.6	11.5	
Unidentified Gerbillinae	2.0	2.4	9.1	9.9	16.5	29.7	3.4	4.8	12.2	18.0	20.3	34.6	18.0	20.3	34.6	
Other <sup>d</sup>	0.3	0.5	2.3	1.1	0.7	2.7	0.0	0.0	0.0	0.4	0.2	7.7	0.4	0.2	7.7	
Unidentified small rodent	1.5	2.2	9.1	0.4	0.1	8.1	0.8	0.7	14.3	1.2	0.8	7.7	1.2	0.8	7.7	
Mammals weighing > 150 g	1.7	0.8	20.5	26.5	10.6	21.6	11.2	8.0	26.5	14.4	8.2	15.4	14.4	8.2	15.4	
Mole rat <i>Cryptomys hottentotus</i>	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.5	4.0	0.0	0.0	0.0	0.0	0.0	0.0	
Ground squirrel <i>Xerus inauris</i>	0.1	0.1	6.8	7.0	2.4	10.8	2.1	1.3	10.2	2.6	3.2	11.5	2.6	3.2	11.5	
Leproid <i>Lepus capensis</i> and <i>L. saxatilis</i>	1.6	0.7	4.5	17.5	6.9	10.8	7.3	5.1	10.2	7.2	4.0	3.8	7.2	4.0	3.8	
Springhare <i>Pedetes capensis</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	
Porcupine <i>Hystrix africaeaustralis</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Springbok <i>Antidorcas marsupialis</i>	0.0	0.0	0.0	2.0	1.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Sheep <i>Ovis aries</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Unidentified mammal	2.9	0.8	6.8	0.9	0.4	2.7	5.8	1.0	12.2	4.5	1.0	3.8	4.5	1.0	3.8	
<b>Plant</b>	<b>0.6</b>	<b>3.2</b>	<b>22.8</b>	<b>3.4</b>	<b>11.3</b>	<b>59.5</b>	<b>31.7</b>	<b>16.3</b>	<b>32.7</b>	<b>14.1</b>	<b>17.1</b>	<b>65.4</b>	<b>14.1</b>	<b>17.1</b>	<b>65.4</b>	
Grass	0.4	1.9	20.5	1.5	8.5	51.4	0.4	2.3	22.4	0.4	2.2	34.6	0.4	2.2	34.6	
Berry/fruit	0.3	1.3	4.5	2.0	2.8	10.8	31.3	14.0	18.4	13.7	14.9	30.8	13.7	14.9	30.8	

<sup>a</sup>includes ants (Formicidae), spiders (Araneae), ticks (Parasitiformes), beetle larvae, snouted termites *Trinervitermes trinervoides*, and unidentified insects.

<sup>b</sup>includes white-toothed shrews *Crocidura* sp. and unidentified shrews.

<sup>c</sup>includes four-striped mouse *Rhabdomys pumilio*, pouched mouse *Saccastomus campestris* and Cape short-eared gerbil *Desmodillus auricularis*.

<sup>d</sup>includes hairy-footed gerbil *Gerbillurus paeba* and southern multimammate mouse *Mastomys coucha*.

also was an important prey species, because although it comprised only 8% of ingested biomass due to its small size, it was found in 48% of scats (Table 1). The second largest share of the diet was rodents weighing 51–150 g, with bushveld gerbil *Tatera leucogaster* being the most important prey species of the group. In terms of ingested biomass, the other food categories only were of marginal importance, even though birds and especially arthropods were regularly consumed. Among the arthropods, the most frequently detected were northern harvester termites *Hodotermes mossambicus* (66% of the scats), beetles (34%) and scorpions (23%; Table 1).

The autumn diet showed a significant difference ( $p < 0.001$ , F-ratio = 4.01) compared to the spring diet. The only significant difference ( $p < 0.001$ , U = 433.0) in individual prey categories between seasons was rodents weighing  $\leq 50$  g, as the ingested biomass of this group declined by more than half (Table 1). Despite this, rodents weighing  $\leq 50$  g were still the most dominant prey category in terms of ingested biomass (33%; Table 1). In contrast to spring, the bushveld gerbil, a rodent weighing 51–150 g, became the most important prey species in terms of ingested biomass (19%). Leporids became the second most important prey species (18% of ingested biomass), which was the highest consumption of any non-rodent species of any season. Autumn was the only season on BGF when ungulates, springbok in this case, were detected, although the amount was minor. Similar to spring, arthropods were regularly consumed (81% of the scats) but were negligible in terms of ingested biomass (1%).

The winter diet on BGF was significantly different to both the spring ( $p < 0.001$ , F-ratio = 8.17) and autumn diets ( $p < 0.001$ , F-ratio = 4.00). The dominating prey category was berries, exclusively from bluebush *Diospyros lycioides*, which was 31% of the ingested biomass (Table 1). The contribution of rodents weighing  $\leq 50$  g fell to 30%

of ingested biomass, which was significantly different to spring ( $p < 0.001$ , U = 565.0) but not autumn ( $p = 0.820$ , U = 851.0). Other important prey categories were rodents weighing 51–150 g (13% of ingested biomass) and leporids (7%). Birds, mainly domestic fowl, reached their highest importance of any season at 7% of ingested biomass. The frequency of consumption of arthropods was less than both spring ( $\chi^2 = 4.6$ ; DF = 1,  $p = 0.032$ ) and autumn ( $\chi^2 = 8.3$ ; DF = 1,  $p = 0.004$ ).

On PR, the winter diet was not significantly different ( $p = 0.130$ , F = 1.53) to the winter diet on BGF. Similar to BGF, the three most important prey items were rodents weighing  $\leq 50$  g, rodents weighing 51–150 g, and berries, although berries were not as important as on BGF. Additionally, the ingested biomass of leporids, ground squirrels, birds, and arthropods were similar between sites. The major difference between sites was that sheep were frequently consumed on PR (19% of scats), although only in small amounts per scat, resulting in a relatively minor part of the total ingested biomass (5%).

On BGF, the estimated annual consumption was 3861 rodent / Cape fox (Table 2), or about 10.6 rodent day<sup>-1</sup> fox<sup>-1</sup>. As a group, more than 10× as many rodents weighing  $\leq 50$  g were consumed than all other groups combined. Numerically, the pygmy mouse was consumed more than any other species. Based on a density of 0.05 Cape fox km<sup>-2</sup> (Kamler et al. 2012b), the estimated number of small rodents consumed per area was 193 rodent km<sup>-2</sup> year<sup>-1</sup>, or 21 238 rodent year<sup>-1</sup> when extrapolated for all of BGF (Table 2).

## Discussion

Murids, mainly gerbil mouse, pygmy mouse, and bushveld gerbil, were the dominant prey of Cape foxes across seasons

Table 2. Estimated number of small and medium-sized mammals consumed by individual Cape foxes *Vulpes chama* on Benfontein Game Farm (BGF; 110 km<sup>2</sup>), South Africa, 2005–2007. Year is extrapolated to a 12 month estimate. Last two columns are based on a density of 0.05 Cape fox km<sup>-2</sup>.

	Spring	Autumn	Winter	Year	Total for 1 km <sup>2</sup> year <sup>-1</sup>	Total for BGF year <sup>-1</sup>
All small rodents	1305.6	983.6	607.7	3861.4	193.1	21 237.6
Rodents weighing $\leq 50$ g	1234.4	880.5	560.9	3566.7	178.3	19 616.9
Pygmy mouse <i>Mus minutoides</i>	299.8	490.6	94.6	1180.1	59.0	6490.4
Gerbil mouse <i>Malacothrix typica</i>	555.7	78.6	114.4	998.2	49.9	5489.9
Gray climbing mouse <i>Dendromus melanotis</i>	153.5	172.9	125.2	602.0	30.1	3311.2
Unidentified Dendromurinae ( <i>Malacothrix</i> / <i>Dendromus</i> )	218.7	138.4	216.2	764.3	38.2	4203.8
Other <sup>a</sup>	6.8	0.0	10.5	23.1	1.2	127.0
Rodents weighing 51–150 g	62.9	100.8	42.4	274.8	13.7	1511.2
Bushveld gerbil <i>Tatera leucogaster</i>	55.0	63.2	30.6	198.4	9.9	1091.2
Unidentified Gerbillinae	6.8	33.8	11.8	69.8	3.5	383.7
Other <sup>b</sup>	1.2	3.9	0.0	6.8	0.3	37.5
Unidentified small rodent	8.3	2.3	4.4	19.9	1.0	109.6
Shrew <sup>c</sup>	10.9	28.0	4.4	57.7	2.9	317.3
Rodents weighing $> 150$ g <sup>d</sup>	trace	2.0	2.9	6.7	0.3	36.8
Leporid ( <i>Lepus capensis</i> and <i>L. saxatilis</i> )	0.2	2.0	0.8	4.0	0.2	22.2

<sup>a</sup>includes four-striped mouse *Rhabdomys pumili*, pouched mouse *Saccastomus campestris* and Cape short-eared gerbil *Desmodillus auricularis*.

<sup>b</sup>includes hairy-footed gerbil *Gerbillurus paebe* and southern multimammate mouse *Mastomys coucha*.

<sup>c</sup>includes white-toothed shrews *Crociodura* sp. and unidentified shrews.

<sup>d</sup>includes mole rat *Cryptomys hottentotus*, ground squirrel *Xerus inauris* and springhare *Pedetes capensis*.



and sites in our study. For example, murids were detected in 78–99% of scats across seasons. The amount of murids in the Cape fox diet was higher than that reported in previous studies (Bothma 1971, Smithers 1971, Lynch 1975, Stuart 1981, Bester 1982, Kok 1996). The difference in importance of murids in Cape fox diets could be related to methodology and sample size, as all previous studies only considered stomach contents, rather than fecal analysis, and sample sizes for four of six previous studies were relatively low (23–66 stomachs). Nevertheless, canid species exhibit a large degree of intraspecific variation in their behaviour and diet, which often is related to differences in the dispersion, diversity, and abundance of food resources (Macdonald and Sillero-Zubiri 2004). Thus, different results among studies could simply reflect differences in available resources. For example, Skinner and Chimimba (2005) stressed there were regional differences in the Cape fox diet, as murids were found almost exclusively in samples from Botswana (Smithers 1971), whereas there was a wider range of small mammal species such as shrews, ground squirrels, mole rats, and leporids in samples from the Free State Province, South Africa (Lynch 1975, Bester 1982).

Only one previous study found berries to be a major (> 15%) part of the Cape fox diet (Bothma 1971). In our study, bluebush berries were found to be an important part in the Cape fox diet in winter on both sites, but a relatively minor part in the other seasons. Differences to previous studies may have been due not only to available resources, but also methodology, as no previous study examined seasonal differences. Consequently, by averaging the diet across seasons, it may not have been possible for previous studies to detect a high consumption of berries as they were only seasonally available. Regardless, our study shows that berries were frequently consumed by Cape foxes in winter, after these berries had ripened and fallen to the ground. Interestingly, we considered fruit-bearing shrubs to be relatively scarce on BGF (Klare et al. 2011b). Therefore, Cape foxes must have actively searched for and frequently visited known places with fruit bearing shrubs, similar to that reported for bat-eared foxes on BGF (Klare et al. 2011b).

Previous studies showed the importance of birds varied significantly among studies, ranging from 4% (Smithers 1971) to 26% occurrence (Lynch 1975). On BGF, although the biomass of birds consumed was relatively low across seasons, the occurrence in scats was as high as 30% in autumn. However, most bird remains appeared to be feathers of domestic fowl, and a small flock of domestic fowl was kept near a farm laborer's residence on BGF, which was close to a Cape fox den. Therefore, the frequent occurrence of feathers in scats, although usually in small amounts, suggested that Cape foxes were scavenging on remains of domestic fowl that had been killed and cleaned by humans, especially because the humans did not report problems with depredation by Cape foxes. Nevertheless, Cape foxes consumed native species of birds in all seasons on both sites, indicating wild birds were a regular part of the Cape fox diet, although usually in low amounts.

Previous research found arthropods to be frequently consumed by Cape foxes, occurring in > 29% of stomach across studies (Bothma 1971, Smithers 1971, Lynch 1975, Stuart 1981, Bester 1982). The most common insects

reported were termites, beetles and orthoptera (Smithers 1971, Lynch 1975, Kok and Nel 2004). Our study showed similar results, as arthropods were found in 35–81% of scats across seasons and sites, and the most commonly consumed insects were termites, beetles, and orthoptera. However, by using correction factors to transform the raw data into biomass consumed, we found arthropods contributed negligibly to the Cape fox diet (Table 1). Thus, even though termites and other insects may have been opportunistically consumed by Cape foxes, overall they were not important food items.

A notable result of our study was the almost complete absence of presumed carrion in the Cape fox diet on BGF. Only 2 of 133 analyzed scats contained remains of large (> 5 kg) mammals (a springbok and a porcupine) indicating scavenging by Cape foxes. In contrast, Bothma (1971) found carrion to be 30% of the stomach volume of Cape foxes, and Lynch (1975) detected carrion in 24% of 58 stomachs analysed. One possible explanation for the difference among studies would be that carrion was rarely available on our study site. However, this was unlikely because black-backed jackal numbers were relatively high on BGF, and jackals fed primarily on springbok (Klare et al. 2010), indicating carcasses must have been available unless jackals completely consumed all carcasses. That said, Cape foxes actively avoided black-backed jackals on BGF due to the threat of intraguild predation (Kamler et al. 2013), thus Cape foxes presumably did not utilize springbok carcasses to reduce their risk of encounter with jackals. Bothma (1971) and Lynch (1975) conducted their studies in areas dominated by sheep farming, where jackals were heavily persecuted and presumably had low densities. Consequently, Cape foxes may utilize carcasses and larger prey to a greater extent in areas where jackal densities are low, although future research is needed to test this hypothesis.

On PR, it was not possible to determine if sheep remains found in Cape fox scats were from predation or scavenging. Nevertheless, that sheep were frequently found in scats (19%), but in low amounts per scat, suggests regular but low levels of scavenging. In contrast, sheep were a major part of the jackal diet in winter on PR in terms of both frequency (41% of scats) and biomass consumed (48%), indicating jackals actively preyed on sheep, especially lambs (Kamler et al. 2012a). Cape foxes may have been able to regularly utilize carcasses on PR, in contrast to BGF, because jackal densities were relatively low on PR due to human persecution (Kamler et al. 2013).

On BGF, individual Cape foxes consumed on average 11 rodents day<sup>-1</sup>, and > 190 rodent km<sup>-2</sup> year<sup>-1</sup> when extrapolated from their density. However, the density of Cape foxes on BGF was extremely low (0.05 Cape fox km<sup>-2</sup>) due to population suppression by jackals (Kamler et al. 2012b, 2013). The estimated density of Cape foxes was higher both on PR (0.14 fox km<sup>-2</sup>; Kamler et al. 2013) and a previous study in the Free State Province (0.3 fox km<sup>-2</sup>; Bester 1982). Assuming that Cape foxes had similar diets that focused primarily on murids, then estimated numbers of rodents consumed on the other sites were 541 and 1158 rodent km<sup>-2</sup> year<sup>-1</sup>, respectively. The above estimates suggest that Cape foxes can consume relatively large number of rodents, and that Cape foxes may be important predators that are capable of limiting rodent

populations, thereby being beneficial to livestock and game farm owners. We recommend future research to determine the impact of Cape foxes on rodent populations, and to examine the spatial and temporal dynamics of Cape fox diets.

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