

## Foraging ecologies of giraffe (*Giraffa camelopardalis reticulata*) and camels (*Camelus dromedarius*) in northern Kenya: effects of habitat structure and possibilities for competition?

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### Abstract

The foraging ecologies of reticulated giraffe (*Giraffa camelopardalis reticulata*) and domestic camels (*Camelus dromedarius*) were examined in the Laikipia District of Kenya, where these species have recently become sympatric. Camels increased popularity in the region has lead to concerns about their environmental impacts and possible competition with wild giraffe for resources. We gathered foraging data on both species using 2-min group scans that recorded feeding heights and plant food preferences. Transects sampled the vegetation in areas where foraging observations were recorded. Giraffe females feed at lower elevations than males, while female camels feed below both sexes of giraffe. There was very little observed overlap in food preferences between the species. However, habitat type has an effect on foraging ecologies of both giraffe sexes, but habitat did not influence camel foraging. Camel herder husbandry techniques also influence camel foraging dynamics. These findings have important implications in achieving the twin objectives of wildlife conservation and pastoralist livestock production in northern Kenya.

**Key words:** camel, conservation, foraging ecology, giraffe, pastoralist

### Résumé

L'écologie alimentaire de la girafe réticulée (*Giraffa camelopardalis reticulata*) et celle du dromadaire (*Camelus dromedarius*) ont été étudiées dans le District de Laikipia.

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au Kenya, où ces espèces sont récemment devenues sympatriques. La popularité croissante des dromadaires dans la région a suscité des inquiétudes au sujet des impacts sur l'environnement et d'une éventuelle compétition pour les ressources avec les girafes sauvages. Nous avons récolté des données sur l'alimentation des deux espèces au moyen de scan de groupe de deux minutes, qui enregistraient la hauteur à laquelle les animaux mangeaient et les plantes préférées. Des transects ont permis de récolter des échantillons de végétation dans les zones où les observations alimentaires ont été faites. Les girafes femelles se nourrissent plus bas que les mâles et les dromadaires femelles se nourrissent plus bas que les girafes des deux sexes. Nous avons observé très peu de recouvrement des préférences alimentaires des deux espèces. Le type d'habitat a un effet sur l'écologie alimentaire des girafes des deux sexes mais il n'influence pas l'alimentation des dromadaires. Les techniques d'élevage des dromadaires influencent aussi la dynamique alimentaire des dromadaires. Ces résultats ont d'importantes implications pour atteindre le double objectif de la conservation de la faune sauvage et de la production d'un bétail pastoral dans le nord du Kenya.

### Introduction

Eastern Africa's semi-arid ecosystems exhibit dynamic interactions between pastoralist cultures, wildlife, complex rainfall patterns and soil types (Kjekshus, 1996). This includes 46 extant free-ranging ungulate species (Owen-Smith & Cumming, 1993), as well as three dominant

livestock species: cattle (*Bos* spp.), goats (*Capra hircus*) and sheep (*Ovis aries*). African herbivores are categorized into a browsing and a grazing guild (du Toit, 1995); within each guild, coexisting species tend to have differing body sizes and feeding strategies (Woolnough & du Toit, 2001). With such complexity, it is vital to better understand how shared food resources partitioned among coexisting species (Sinclair, 1979; Butt & Turner, 2012).

Competition between herbivores depends on numerous factors, and African ungulate guilds partition existing plant resources along temporal and spatial axes (McNaughton & Georgiadis, 1986; du Toit, 1990). Considering the spatial axis, browser species maximize nutritional and energetic intake by focusing their feeding on different heights of vegetation (Pellew, 1984; Cameron & du Toit, 2007). Although there is a clear stratification in feeding preferences, overlap does exist (du Toit, 1990). Such overlap in resource usage sets the stage for possible competition for browse resources (see Prins & Fritz (2008)).

Pastoralist livestock systems occur across much of the East African savannah, with livestock herds often overlapping spatially with wild herbivores, and utilizing the same resources. In areas where such livestock grazing occurs, it represents an added layer of pressure on the vegetation available for wild herbivores. Livestock feeding and husbandry could have significant knock-on effects on the functioning and structure of the savannah system, as well as on the availability of browse (Butt & Turner, 2012).

However, a species that exists alongside people, livestock and wild ungulates – the giraffe (*Giraffa camelopardalis reticulata* de Winston) – has been thought to escape such resource overlap with either wildlife or livestock (Ciofalo & Le Pendu, 2002). This is primarily due to giraffe's capacity to feed on vegetation out of reach of other ruminants, and its ability to travel long distances in search of forage (du Toit, 1990; Young & Isbell, 1991; Bond & Loffell, 2001; Woolnough & du Toit, 2001; Parker & Bernard, 2005; Fennessy, 2009).

Pastoralist herders aim to manage their livestock for maximum productivity with respect to environmental conditions (Galvin, 1992; Ellis & Galvin, 1994; Galvin, Coppock & Leslie, 1994). Changes in climate and more frequent droughts represent a serious challenge to African pastoralists (Davies & Bennett, 2007; Homewood, 2008; Butt, 2010; Kiage, 2013). One way pastoralists have dealt with aridity in some environments is to change herd composition from cattle-dominated groups to including sheep and goats or even camels (*Camelus dromedarius*

Linnaeus). Domestic camels are more drought tolerant than cattle, performing well in adverse conditions, and have lower energy requirements (Farid, 1995; Maloiy, Rugangazi & Rowe, 2009).

Camel foraging is under studied (Dereje & Uden, 2005). Few studies exist currently on the effects of introduced camels on ecosystem function and the resident herbivore communities. Camel browsing may affect forage availability, vegetation composition or structure. One particularly important relationship could exist between domestic camels and reticulated giraffe. Both are large ungulate browsers, with the ability to feed across a large vertical spectrum.

This research explores the foraging preferences of domestic camels and wild reticulated giraffe by investigating:

- 1 Is there overlap between camel and giraffe feeding heights and preferred plant food species?
- 2 Are there differences between adult female and adult male giraffe foraging ecologies across habitat types?

## Methods

### Study area

Field data were gathered between May and August 2011 on the 19,873 ha Mpala Research Centre (MRC) in Laikipia Province (north central Kenya). Camels are kept as livestock at MRC, providing the opportunity to compare the foraging ecologies of domestic camel and the coexisting wild reticulated giraffe.

Camels are managed at MRC in a quasi-pastoralist fashion; herded during the day, and returning each evening to a *boma* (temporary animal enclosures built either of cut acacia branches or of mobile metal fencing).

Western Mpala is composed of topographically flat, 'black cotton' vertisol (clay) soils characterized by extreme shrink-swell movements, that destroy the roots of most plant species (Pringle *et al.*, 2010). This produces a low diversity savannah with 97% over story cover of *Acacia drepanolobium* Harms ex Y. Sjöstedt, and ground cover composed of five grass species and two forbs (Young, Stubblefield & Isbell, 1997; Young *et al.*, 1998).

Eastern and northern Mpala is composed of infertile red sandy loams (alfisols; locally termed 'red soil'). This soil type supports a diverse, structurally variable bushland habitat with a patchy understory of perennial grasses, and a canopy cover dominated by *A. brevispica* Harms, *A. mellifera* Benth and *A. etbaica* Schweinf (Augustine & McNaughton, 2004; Kinnaird & O'Brien, 2012).

Between these areas is a transition zone, which supports a savannah dominated by perennial grasses with widely spaced shrubs, including species from both the black cotton and red soil habitats (see Fig. 1). These three soil types produce vegetation types that are very different in species richness, and result in distinct habitat structures (Augustine & McNaughton, 2004; Kinnaird & O'Brien, 2012), allowing for comparison with herbivore foraging ecology across these three soil types.

#### Behavioural observations

To determine overlap in feeding height and plant food species preferences between giraffe and camels, spatially explicit 2-min behavioural group scans (Altmann, 1974; Böving & Post, 1997; Hamel & Cote, 2008; Treydte *et al.*, 2011) were used to record frequency of feeding at different height categories, as well as the frequency of feeding on

plant species (See Fig. S1, Tables S1 and S2). Only data from adult giraffe and adult female camels are included here. Male camels were not observed due to low stocking numbers and field time limitations.

#### Reticulated giraffe surveys and observations

Giraffe were surveyed between 6:30 am and 11:00 am and again from 3:00 pm to sunset, to avoid the midday period when animals are least active (Pellew, 1984). Observations were vehicle-based for safety and to minimize disturbance. The study area was divided into six sections (Fig. 1) that were visited in rotation to allow for even distribution of sampling effort across MRC.

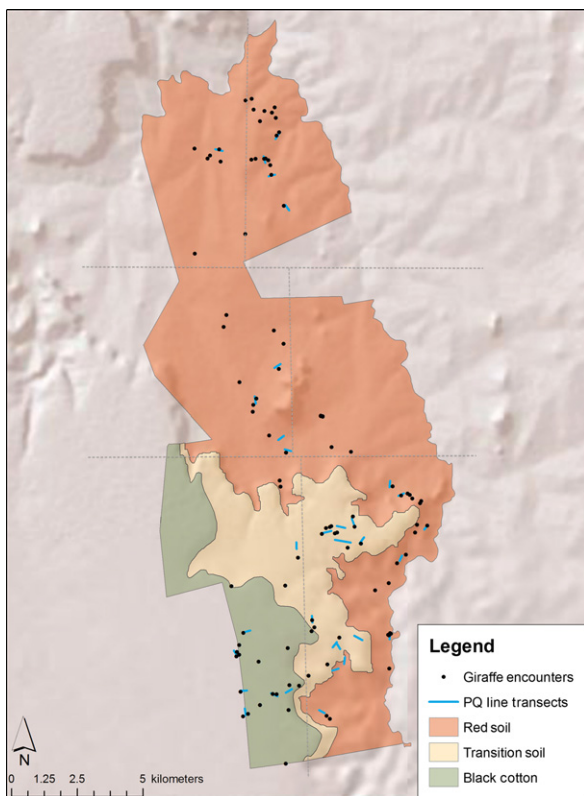
When giraffe were encountered a GPS waypoint, the number and sex of visible giraffe were recorded. The distance to the giraffe was measured by a laser rangefinder, and the bearing angle was taken using a handheld compass. This allowed for exact positioning of the giraffe in the landscape using GIS trigonometry functions (ArcGIS 10, Fig. S2). When the encounter ended, the GPS location, distance and compass bearing to the group/animal's last location were again recorded. This allowed for straight-line approximation of the giraffe's browsing movement (vectoring) through the landscape.

To quantify giraffe feeding heights, four feeding height categories were assigned based on the angle subtended between the neck and forelegs (Fig. 2): feed high 180°, feed medium 135°, feed level 90° and feed below 45° (du Toit, 1990). The actual heights of each feeding category were measured on plants (du Toit *pers. comm.*). After observing a giraffe foraging at one of the height categories on a plant, that same plant was visited after the giraffe's departure and the bite mark height above ground level was measured using wooden poles marked in 50-cm increments (Fig. 2 and Table S3).

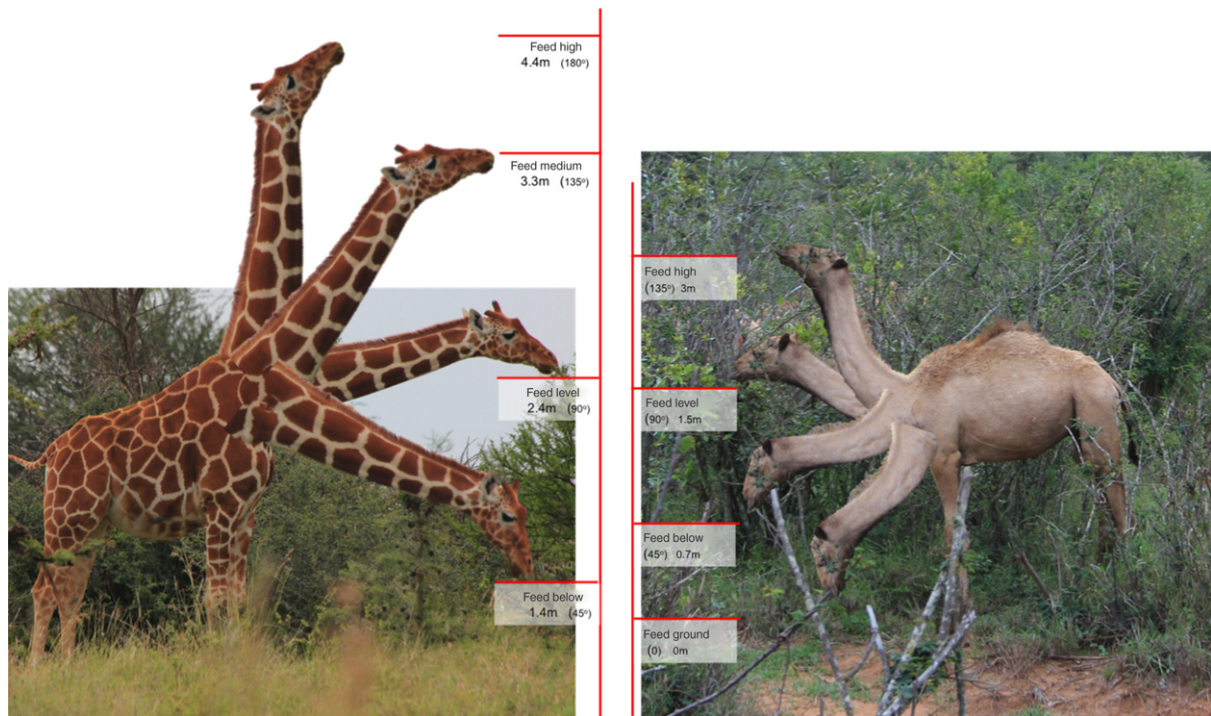
#### Camel surveys and observations

Observations were made on the single accessible herd of camels over five days. The herd consisted almost exclusively of adult, breeding females, with between 3 and 5 males, as well as several young and juveniles. The observer walked with the herders amidst the camels as they foraged across the landscape.

Scan observations were conducted in 1-h increments, followed by a break to avoid observer fatigue. A GPS waypoint was taken at the beginning and end of each of



**Fig 1** Map of study area (19,873 ha), showing the three primary soil types, giraffe encounters, and vegetation transect lines. Grey lines outline the six sampling sections. Projection: USGS 1984 UTM 37N. Source: The Mpala Research Centre, Nanyuki Kenya (soil type), BingMaps aerial (2010)



**Fig 2** Photo illustration showing the giraffe and adult female camel feeding height categories and neck angles. (Not to scale. Giraffe and camel in photo illustrations are based on images of adult females)

the hour-long observation periods. This allowed for vectoring of the movement of the camel herd during the observation periods, as well as for comparisons with giraffe.

For each 2-min group scan, observations were recorded of the first twenty adult female camels seen, although this number was reduced to fifteen after the first three days of observations, due to the difficulty of recording 20 camels at a time. Observations were not made during periods of active herding.

Camel feeding height categories are based on the angle subtended between the neck and forelegs (Fig. 2): feed high 135°, feed level 90°, feed below 45° and feed ground (grazing). To measure the height of each of the feeding height categories, the heights above ground of the heads of fifteen adult female camels were measured when held approximately at middle of each category (head held high, shoulder level and knee level) while in the boma (du Toit *pers. comm.*).

#### Vegetation transects

To measure the vertical structure and relative density of plant species, 33 transects were conducted along observed

browsing vectors of giraffe and camels (Fig. 1) to allow sampling of the vegetation and habitat structure that the animals browsed in. Each transect had a minimum length of 250 m. Point-centred quarter samples (PQ samples) were taken every 25 m along the transect line (Pellew, 1983; Young & Isbell, 1991; Cornelissen *et al.*, 2003; Mitchell, 2007) so that there was a maximum of ten PQ samples per transect. In each PQ quarter, the distance to the branch end of the nearest live woody plant taller than 0.8 m was measured using a 100-m tape measure. The height of the plant was also measured to the end of its highest branch using a fibreglass telescoping tree measurement pole.

#### Statistical analysis

For comparison of feeding heights within and between species, pooling and then averaging each animal's feeding height data over the observation period minimized the possibility of nonindependence of observations. This resulted in a single averaged feed height for each animal for each observation period. For encounters with large herds, where observations were not tracked to individuals

–the aforementioned ‘animals’ may not have been the same individual, and in such cases, they were categorized as composite animals (Table S5).

To examine the foraging overlap between camel and giraffe, unaveraged feeding height data were used to analyse the feeding heights on plant species (Tables 1 and 2). As such, those results should be interpreted with caution due to the possibility that the data are not independent.

Data were tested for normality using the Shapiro–Wilk test. Nonparametric tests were used for non-normal data. The feeding heights of camels and giraffe on plant species were analysed using Mann–Whitney *U*-tests. Multiway ANOVAs and Tukey’s HSD pairwise comparisons were used to determine the influence of habitat type and sex on the feeding heights of giraffe, using summarized data.

## Results

### Occurrence and feeding height categories

Feeding height data ( $n = 3617$ ) were recorded for 337 giraffe across 85 encounters (Fig. 1 and Table S6). However, these may not all be unique individuals, as a given giraffe may have been repeatedly sighted on different days.

Female camel herd size varied between 62 and 78 individuals. Our survey produced 7340 feeding data observation points (Table S7).

Figure 2 (Tables S3 and S4) shows the results of the giraffe and camel feeding category measurements.

### Giraffe and Female camel feeding height comparison

Average feeding height data were compared between giraffe ( $n = 337$ , individual feed height  $\bar{x} = 3.0$  m) and camels ( $n = 340$ , individual feed height  $\bar{x} = 1.36$  m). Female camels fed significantly lower than giraffe (Mann–Whitney *U*-test,  $U = 2567$ ,  $P < 0.001$ ) (Fig. 3). This difference remained significant ( $U = 2538.5$ ,  $P < 0.001$ ) even after the giraffe observations from black cotton habitat were removed (giraffe  $n = 284$ , median individual average feed height = 2.93 m).

When camel feed heights were separately compared to male ( $n = 129$ ) and to female giraffe feeding heights ( $n = 155$ ), camels still feed significantly lower than male giraffe ( $U = 34.5$ ,  $P < 0.001$ ) and female giraffe ( $U = 2504$ ,  $P < 0.001$ ) (Fig. 3).

**Table 1** (A) Adult giraffe mean feeding heights<sup>a</sup> per plant species. (B) Mean plant species heights from all of Mpala (transect  $n = 33$ )

(A)	(B)				n
	Female mean feed height $\pm$ SE (n)	Male mean feed height $\pm$ SE (n)	Pooled mean feed height $\pm$ SE (n)	Mean plant height $\pm$ SE (m)	
Adult giraffe plant food species					
<i>Acacia brevispica</i>	1.86 $\pm$ 0.17 m (26)	2.75 $\pm$ 0.27 m (21)	2.26 $\pm$ 0.16 m (47)	1.89 $\pm$ 0.04	255
<i>Acacia drepanolobium</i>	1.82 $\pm$ 0.04 m (485)	3.63 $\pm$ 0.08 m (229)	2.40 $\pm$ 0.05 m (714)	2.46 $\pm$ 0.07	321
<i>Acacia etbaica</i>	2.67 $\pm$ 0.07 m (182)	3.52 $\pm$ 0.08 m (148)	3.05 $\pm$ 0.06 m (330)	3.33 $\pm$ 0.10	174
<i>Acacia mellifera</i>	2.29 $\pm$ 0.03 m (712)	3.23 $\pm$ 0.05 m (355)	2.60 $\pm$ 0.03 m (1067)	2.80 $\pm$ 0.06	367
<i>Acacia nilotica</i>	NA	2.03 $\pm$ 0.33 m (3)	2.03 $\pm$ 0.33 m (3)	2.30 $\pm$ 0.16	17
<i>Balanites glabra</i>	NA	3.16 $\pm$ 0.38 m (8)	3.16 $\pm$ 0.38 m (8)	3.53 $\pm$ 0.35	17
<i>Boscia albitrunca</i>	3.84 $\pm$ 0.06 m (107)	4.67 $\pm$ 0.07 m (27)	4.0 $\pm$ 0.06 m (134)	4.05 $\pm$ 0.23	24
<i>Croton dichogamous</i>	1.1 $\pm$ 0.00 m (1)	NA	1.1 $\pm$ 0.00 m (1)	1.73 $\pm$ 0.05	146

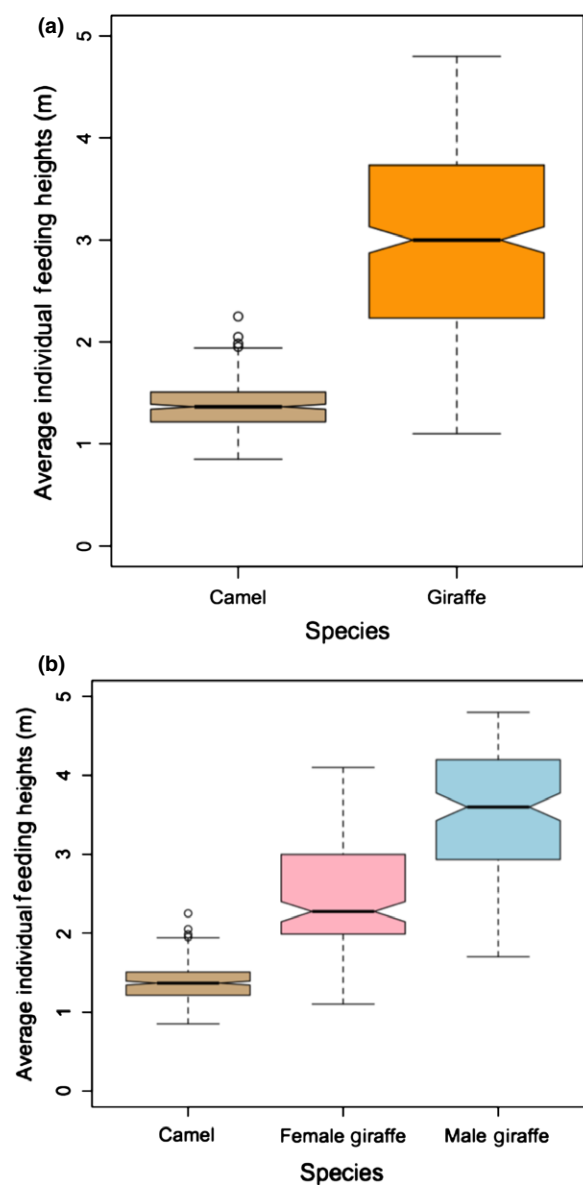
<sup>a</sup>Feed height data are the actual observations, not aggregates to individual giraffe, and thus may not be independent.

**Table 2** (A) Adult female camel mean, median and standard deviation of plant species feeding heights<sup>a</sup>. (B) Mean plant species heights from all of Mpala (transect n = 33)

(A)		(B)				
Camel plant food species	Mean feeding height (m)	Median feeding height (m)	SE feeding height (m)	n	Mean plant height ± SE (m)	n
<i>Acacia brevispica</i>	1.26	0.7	0.01	2337	1.89 ± 0.04	255
<i>Acacia etbaica</i>	1.79	1.5	0.08	111	3.33 ± 0.10	174
<i>Acacia mellifera</i>	1.67	1.5	0.05	283	2.80 ± 0.06	367
<i>Acacia nilotica</i>	1.40	1.5	0.09	46	2.30 ± 0.16	17
<i>Acacia</i> spp.	1.54	1.5	0.12	40	NA	NA
Indeterminate <sup>b</sup>	1.30	0.7	0.02	1324	NA	NA
<i>Croton dichogamous</i>	1.13	0.7	0.06	85	1.73 ± 0.05	146
<i>Euclea</i> spp.	1.45	1.5	0.05	267	NA	NA
<i>Boscia albitrunca</i>	2.13	3.0	0.06	215	4.05 ± 0.23	24

<sup>a</sup>Feed height data are the actual observations, not aggregates to individual giraffe, and thus may not be independent.

<sup>b</sup>Indeterminate: species indeterminate, most likely either *Croton dichogamous* or *Euclea* spp.



**Fig 3** (a) Mean composite individual camel and giraffe feeding heights. Camels fed lower than giraffe (Mann-Whitney U, U = 2567, P < 0.001). (b) Mean composite individual camel and giraffe (male and female) feeding heights. Camels fed lower than both male (U = 34.5, P < 0.001) and female giraffe (U = 2504, P < 0.001). Thick indented line represents median values, colored areas show the range of the upper and lower quartile. Range of the minimum and maximum values (excluding outliers) are shown by the dashed lines. Empty circles indicate the outliers

To investigate whether differing habitat structure might explain these differences, the plant transects taken along giraffe browsing paths (transect n = 22, plant n = 968)

from red soil and transition soil habitat were compared to the plant transects taken along camel browsing vectors (transect  $n = 5$ , plant  $n = 220$ ). The median height of the vegetation along camel browsing vectors ( $\theta = 1.75$  m) was significantly lower than that of giraffe browsing paths ( $\theta = 2.18$  m) using Mann–Whitney  $U$ -test ( $U = 81296.5$ ,  $P < 0.001$ ).

#### Influence of habitat type and sex on adult giraffe foraging

Giraffe exhibit a significant difference in average feeding heights between males and females. Males feed on average at 3.7 m while females feed at 2.5 m (ANOVA  $F_{1,331} = 254.7$ ,  $P < 0.001$ ,  $n = 337$ ). Indeed, across all three habitat types, male average feeding heights remained significantly higher than female (black cotton: ANOVA  $F_{1,51} = 48.0$ ,  $P < 0.001$ ; red soil: ANOVA  $F_{1,199} = 135.3$ ,  $P < 0.001$ ; transition soil: ANOVA  $F_{1,81} = 102.1$ ,  $P < 0.001$ ) (Fig. 4).

Habitat had a significant effect on giraffe feeding (ANOVA  $F_{2,331} = 90.3$ ,  $P < 0.001$ ). The median heights of vegetation in each habitat were significantly different (Kruskal–Wallis  $H = 79.6$ ,  $P$ -value  $< 0.001$ ). Average feeding heights were highest in the black cotton soil and lowest in the transition soil, for both sexes, mirroring the pattern of median vegetation heights.

Males exhibited significant differences in their average feeding heights across all three habitat types (ANOVA

$F_{2,151} = 44.8$ ,  $P < 0.001$ ). Females showed some similar significant differences (ANOVA  $F_{2,180} = 46.9$ ,  $P < 0.001$ ); however, there was no difference between adult female feeding heights in the black cotton and red soil habitats (Tukey's HSD  $P = 0.09$ ), but that they were significantly lower in transition soil ( $P < 0.001$ ) (Fig. 4).

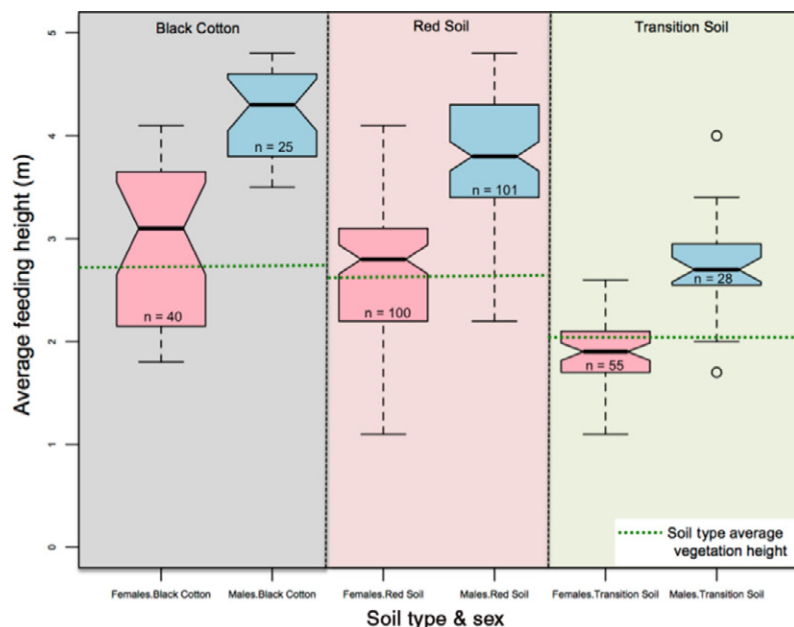
#### Giraffe food plants

Adult giraffe were observed to feed on eight identified woody plant species across Mpala (Table 1), whereas plant transects recorded fifteen species of woody plants (Table S8).

Further analysis was conducted on the four plant species with the most feeding observations (*A. mellifera*, *A. drepanolobium*, *A. etbaica* and *Boscia albitrunca* Gilg & Gilg-Ben). Male giraffe consistently feed significantly above the median height of the plant for *A. drepanolobium* (Mann–Whitney  $U$ -test,  $U = 17,371$ ,  $P < 0.001$ ), but the difference is not significant for *A. etbaica* ( $P = 0.1$ ) or *B. albitrunca* ( $P = 0.052$ ).

In contrast, female giraffe feed significantly below the median heights of *A. drepanolobium* (Mann–Whitney  $U$ -test,  $U = 106765.5$ ,  $P < 0.001$ ) and *A. etbaica* ( $U = 20,153$ ,  $P < 0.001$ ), but not for *B. albitrunca* ( $P = 0.4$ ).

Only *A. mellifera* was found in all three habitat types, and it showed a significant difference in its median height



**Fig 4** Mean composite individual giraffe feeding heights across the three soil types. Male average feeding heights are significantly higher than female (ANOVA - Black Cotton:  $F_{1,51} = 48.0$ ; Red Soil:  $F_{1,199} = 135.3$ ; Transition Soil:  $F_{1,81} = 102.1$ , all  $P < 0.001$ ). Thick indented line represents median values, colored areas show the range of the upper and lower quartile. Range of the minimum and maximum values (excluding outliers) are shown by the dashed lines. Empty circles indicate the outliers

across habitats (Kruskal–Wallis  $H = 20.4$ ,  $P$ -value  $< 0.001$ ), except for between black cotton and transition soil ( $P$ -value = 0.3). Overall, female giraffe feed significantly lower than the median height of *A. mellifera* (Mann–Whitney  $U$ -test,  $U = 164,377$ ,  $P < 0.001$ ), while males feed significantly higher (Mann–Whitney  $U$ -test,  $U = 48420.5$ ,  $P < 0.001$ )

In the black cotton soil, females do not feed higher than the median height of the plant (Mann–Whitney  $U$ -test,  $U = 224$ ,  $P = 0.09$ ), but it is a small sample size (plant height  $n = 15$ , feeding height observations  $n = 45$ ). In red soils, females feed significantly above the median plant height (Mann–Whitney  $U$ -test,  $U = 16,593$ ,  $P < 0.001$ ). While in the transition soils, females feed significantly below the height of the plant (Mann–Whitney  $U$ -test,  $U = 46101.5$ ,  $P < 0.01$ ). Males on the other hand feed significantly higher than *A. mellifera*'s median height in all habitats (black cotton:  $U = 10$ ; red soil:  $U = 13,837$ ; transition soil:  $U = 8807$ , all  $P < 0.001$ ).

#### Camel food plants

Camels were observed to feed on six identified species (Table 2). Three additional plant categories were not identified to species level. Average feeding heights ranged from 1.13 to 2.13 m. Ground level feeding was removed from analysis due to their zero height value.

The four most frequently fed upon plant species were analysed further. Camels fed significantly below the heights of *A. brevispica* (Mann–Whitney  $U$ -test,  $U = 462,318$ ,  $P < 0.001$ ), *A. mellifera* ( $U = 80,223$ ,  $P < 0.001$ ), *A. etbaica* ( $U = 16,005$ ,  $P < 0.001$ ) and *B. albitrunca* ( $U = 4525$ ,  $P < 0.001$ ).

## Discussion

Results suggest no direct overlap in the feeding heights of adult female camels and adult giraffe of either sex (Fig. 3). Giraffe and camel do overlap in consumption of six plant species on Mpala, but of the four most frequent species eaten by each, overlap only occurs with *A. mellifera* (Tables 1 and 2). Although *A. mellifera* makes up 44% of a giraffe's foraging compared to 6% of a camel's. Using frequency as an indicator of preference at Mpala, giraffe and female camel prefer two very different plant palettes (see Tables 1 and 2). Similarly, feeding is concentrated at different mean heights, 3.0 m for giraffe and 1.36 m for female camels (Fig. 3a).

Another explanation for the divergence in giraffe and camel food preferences is that vegetation densities are different where camels foraged compared to areas where giraffe foraged. The overall height of camel-fed vegetation was significantly lower than the height of giraffe-fed vegetation. The relative and absolute densities of plant species in the camel's foraging areas also differed compared to densities of plants where giraffe fed. The densities of *A. brevispica* and *B. albitrunca* were higher where camels fed, while *A. etbaica* and *A. mellifera* were lower. Thus vegetation structure may be driving the differences in preference between camels and giraffe rather than preference.

Previous research from Ethiopia has shown similar camel plant food preference results to those found in this study. They found that during the wet season *A. brevispica* is the camel's favourite food item (22% of diet), while *A. mellifera* is less favoured (8%) and *Boscia* spp. (<1%) is rarely eaten (Dereje & Uden, 2005). These findings mirror those of our study (Table 2). Potentially, these camel plant food preferences could be widespread, and not a peculiarity of plant densities at Mpala.

However, human management practices influence foraging dynamics of camels (Farah *et al.*, 2004; Dereje & Uden, 2005; Gallacher & Hill, 2006a). Herders dictate the plant community camels have access to, which may also affect how camels browse. In addition, camel bomas are relocated periodically once the surrounding vegetation is degraded. If a boma is moved to a location with vastly different habitat structure, then that may alter the camels foraging ecology. Further research examining the foraging response of camels to herder influence or changed boma locations could uncover whether camel's preferences are innate or a response to the vegetation structure and densities of their localized habitat and husbandry techniques.

Foraging by camels has been shown to impact plant community composition (El-Keblawya, Ksiksi & El Alqamy, 2009), they can drive a shift from *Acacia* savannah to low dwarf scrub (Gallacher & Hill, 2006b). How the plant community at Mpala will respond to camel browsing is unknown, as is the extent of any knock-on effects on giraffe and other wild herbivore communities, especially because camel distribution is patchy and boma centric at Mpala.

Interest is growing among pastoralist communities to raise camels as livestock to diversify their herds in the face of uncertainty and to maximize livestock production (Desta & Coppock, 2000; Young *et al.*, 2013; Kinnaird, M. & O'Brien, T. *pers. comm.*). Understanding the effects of



increased camel populations on arid rangelands and their effect on availability of browse for wildlife (including giraffe) is invaluable to inform effective management and continued sustainable livestock-wildlife interactions (Retzer, 2006). This management is critical as giraffe populations are declining (Tutchings *et al.*, 2013), and the impacts of large herbivores on this ecosystem are complex and often counterintuitive (Pringle *et al.*, 2011).

Giraffe and camel have a wide vertical choice when foraging, and these results show an absence of foraging height overlap with each other. More data are needed to determine whether the drivers of these differences are the result of different vegetation communities where these animals are foraging, or are due to differential preferences by the two species. There is pressing need for further research, especially if pastoralist and ranching management trends continue to bring these two large, iconic and fascinatingly complex ungulates together.

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## Supporting information

Additional Supporting Information may be found in the online version of this article:

**Table S1** Methods used to collect data for each research question.

**Table S2** Statistical tests used to analyze data for each research question.

**Table S3** Giraffe feeding height categories and measurements.

**Table S4** Camel feeding height categories and measurements.

**Table S5** Numbers of tracked and composite giraffe.

**Table S6** (a) Pooled adult giraffe feeding heights. (b) Adult giraffe feeding heights by sex.

**Table S7** Camel feeding heights.

**Table S8** (a) Total number of plants measured for height on PQ transects (n = 1452). (b) Plant species Mean, Median & SD height (m).

**Figure S1** Flow chart detailing the method and data recorded during giraffe behavioral observations.

**Figure S2** Photo illustration of how the vehicle-based GPS waypoints of giraffe encounters were moved using field metadata and ArcGIS trigonometry to represent the real location of the giraffe in space (not to scale).