

Nonhuman primates and cattle: a camera trap survey of inter-specific spatial and temporal overlap

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Abstract – Nonhuman primates are threatened across their distribution, with habitat loss, disease, poaching, and the pet trade causing widespread population decline. An understudied threat is the growing presence of cattle in primate habitat, with the increased exposure to human and bovid pathogens, domestic dogs that accompany herders, and habitat degradation. We investigated cattle-primate spatial and temporal overlap using 13 motion triggered cameras over a 16-month period (2023-2024). We detected cattle and primate presence in 5/13 cameras, all in open vegetation (woodland or grasslands). Yellow baboons and vervet monkeys spatially overlapped with cattle, whilst chimpanzees and red-tailed monkeys were only observed in riparian forests, and so did not overlap with cattle. We found no relationship between primates and cattle observations ($r^2 = 0.49$, n = 12, p = 0.1), suggesting that there is no avoidance between species but we did find an effect of season on primate activity on cattle-present vs cattle-absent cameras (χ^2 (1, N = 176) = 7.21, p = 0.007), with more primate observations on cattle-present cameras during the dry season. Primates and cattle observed on the same cameras exhibited similar diel activity patterns, compared to earlier and later primate presence in non-cattle cameras. We conclude by discussing the implications for cattle-primate overlap, and next steps to better understand this coexistence.

Keywords - anthropogenism, East Africa wildlife, livestock, remote monitoring.

Introduction

Nonhuman primates (hereafter, primates) are threatened across their distribution, with habitat loss, disease, poaching, and the pet trade causing widespread population decline (Estrada *et al.*, 2017). Less common, but an increasing pressure on wild primate populations is sharing space with livestock, especially cattle. Cattle herding degrades ecosystems, often resulting in bushland and invasive species that exploit the disappearance of indigenous plant species (Hudak, 1999; Tobler *et al.*, 2003). Wildlifelivestock conflict has been central to conservation challenges for half a century, especially in Africa (Fynn *et al.*, 2016) In fact, conservation action plans often now include mitigation strategies to address competing livestock and wildlife land use needs (Baloi and Chaminuka, 2017). It is thus surprising that primate-livestock conflict is a rarely investigated topic.

Livestock can result in direct and indirect threats for primates, with the most commonly described threat being cross-species disease risk for primates. In the first study to assess parasite diversity and richness (gastrointestinal helminths) across a sympatric community of livestock, wild ungulates, and primates in southern Kenya, none of the bovids (cattle or wild ungulates) shared helminths with sympatric baboons (Papio cyncephalus) or vervet monkeys (Chlorocebus pygerythrus). Where primates and bovids did share pathogens (e.g. Trichuris spp.), hosts harboured different morphotypes (Obanda et al., 2019). The authors concluded that the richness of the primate parasite community was entirely zoonotic and thus represented a risk to surrounding pastoralist (human) groups (namely, the Masai), but was not particularly at risk of transmission from cattle.

In Kibale National Park (Uganda), Escherichia coli bacteria (genetic) similarity between three primate species (Cercopithecus ascanius, Procolobus refomitratus and Colobus guereza) and humans increased almost threefold as disturbance intensity increased. Similarity with humans was greatest in red-tailed monkeys (Cercopithecus ascanius), which are known to crop forage in the area, and thus were more directly exposed to humans and livestock (Goldberg, 2008). In a related follow-up study in the same area, a similar pattern was observed for Giardia, when cattle, goats, and sheep were also sampled as potential vehicles for pathogens across primate species (including humans) (Johnston et al., 2010). Livestock have also been implicated for Giardia transmission between black and white howler monkeys (Alouatta caraya) in northern Argentina (Kowalewski et al., 2011). In summary, there are important, health-related risks for primates when living near cattle.

There is nonetheless a paucity of evidence describing which populations live in proximity to livestock and whether risk changes over time or space. In the Issa valley, western Tanzania, chimpanzees (*Pan troglodgytes schweinfurthii*) periodically encountered cattle in miombo woodlands (Fryns *et al.*, 2021). There, chimpanzees remained vigilant of cattle and herders, but did not otherwise alter their behaviour. At the same site, the only observations of direct threats from cattle/herders to chimpanzees involved domestic dogs that often accompany herders. In the first observation, two dogs were observed chasing chimpanzees into a tree, under which the dogs remained for >30 minutes, while chimpanzees warning barked repeatedly (C. Giuliano, personal communication). In the second example, a pack of dogs chased, caught, and killed a mother and infant chimpanzee, before being chased off by researchers (Piel and Stewart, 2019).

Given the likely spatial overlap of primates and cattle, especially in East Africa, far more attention is necessary to assess the extent to which primates experience temporal or spatial overlap with cattle and how this might affect primate behaviour. For example, in typical predator-prey contexts, prey species may either adjust diel patterns to avoid predators (Tambling et al., 2015; Cunningham et al., 2019), or else avoid areas entirely (Sih, 2005). Not only are data on livestock grazing patterns generally not available in many places (but see Moyo et al., 2013; Schieltz et al., 2017), the vastness of grazing areas makes direct study of the primate-cattle intersection a logistical challenge for primatologists and conservationists alike, as without remote monitoring (e.g., radio collars), researchers can generally not follow primates throughout cattle herding. To investigate questions about space use between wild primates and domestic cattle, we analysed video data from motion triggered cameras (camera traps – CTs) deployed in the Issa valley, western Tanzania to address the following questions:

- (1) Do cattle spatially and temporally overlap with primates, and if so, with which (primate) species, in what vegetation type, and in which seasons do we see the most intense rates of overlap?
- (2) Compared to CTs with no observed cattle, do we see any hourly shifts in primate activity as a strategy to avoid direct competition?

We hypothesized that primate-cattle overlap intensity would be predicted based on species habitat preference with the highest overlap between cattle and primates that have similar

	Species	Diet	Habitat preference	Reference
Nonhuman primate	Chimpanzee (Pan troglodytes)	Frugivorous omnivore	Closed-canopy forest, woodland mosaics	Lindshield <i>et al.</i> (2021)
	Yellow baboon (<i>Papio cynocephalus</i>)	Generalist	Woodland mosaics, grasslands	Norton <i>et al.</i> (1987)
	Red-tailed monkey (<i>Cercopithecus ascanius</i>)	Frugivorous omnivore	Riparian forests, woodland-forest-edges	Bryer <i>et al.</i> (2013); Fornof <i>et al.</i> (2023)
	(<i>Chlorocebus</i> <i>pygerythrus</i>)	Omnivore	Grasslands, woodlands, riparian forests, Acacia/montane forests	Herzog <i>et al.</i> (2020)
Cattle	Bos taurus	Herbivore	Grasslands	Fritz et al. (1996)

Table 1. Study species diet and habitat preferences.

habitat preferences (Table 1), e.g., highest cattle overlap with yellow baboons and vervets and the lowest overlap would be between cattle and red-tailed monkeys or chimpanzees. We further hypothesized that overlap would intensify in the post-fire period (late dry season), when burned vegetation gives way to fresh forage for cattle and primates that exploit woodland fruits. Finally, in those areas of overlap, we expected primates to show temporal offsetting behaviour, increasing activity in early morning and evening to avoid encounters with cattle, which are active mid-day (given time to depart and return to corrals).

Methods

STUDY SITE

The Issa valley is in western Tanzania, in the northern part of the Greater Mahale Ecosystem (GME), 80 km east of Lake Tanganyika, nearly equidistant between Gombe and Mahale Mountains National Parks (Figure 1). The region is characterised as a mosaic habitat, dominated by open (miombo woodland, seasonally inundated grasslands, and rocky outcrops) and closed (evergreen riparian forest) vegetation (Drummond-Clarke et al., 2022). Annual rainfall averages 1250 mm (and falls entirely between October and April). Average daily mean temperature ranges from 11-35°C. Issa is characterised by its diverse mammalian wildlife of both medium-large (Piel et al., 2018) and small (D'Ammando et al., 2022)



📕 Issa station 🔴 Woodland 🔵 Riparian 🔿 Outcrop 💛 Grassland

Figure 1. Map of the Issa valley study area, and the locations of 13 motion triggered cameras. Camera symbols reflect the vegetation type (green, riparian; orange, woodland; yellow, grassland; grey, rocky outcrop).

species, including apex predators lions (*Pan-thera leo*), leopards (*P. pardus*), and hyenas (*Crocuta crocuta*), as well as six diurnal primate species: chimpanzees, yellow baboons, red colobus (*Piliocolobus tephrosceles*), blue (*Cer-copithecus mitis*), red-tailed (*C. ascanius*), and vervet (*Chlorocebus pygerythrus*) monkeys.

Tuble 2. Camera hap videos recorded of each taxon in each vegetation type.								
Camera	Vegetation	Primates	Cattle	Predators	Poachers	Other wildlife	Total	
1315	Riparian	19		1		89	109	
1348	Riparian	1		2		199	202	
4800	Riparian	79		23		458	560	
7224	Grassland		338	1	7	314	660	
7226	Outcrop	49		5		20	74	
7257	Grassland		15	0		23	38	
7259	Woodland	2	6	0	1	68	77	
7261	Woodland	15	97	0		55	167	
7278	Outcrop	18		1	1	95	115	
7279	Grassland		163	0		138	301	
7281	Woodland	15	44	0		176	235	
7791	Grassland	20	115	0		537	672	
8857	Woodland	3	60	7		44	114	
Total		221	838	40	9	2216	3324	

Table 2. Camera trap videos recorded of each taxon in each vegetation type.

DATA COLLECTION

We analysed data from 13 motion-triggered, infrared CTs (Browning Strike Force, Bushnell Trophy Cam HD Aggressor; and Reconyx Hyperfire 2 HF2X) at Issa over a 16-month period (January 2023-April 2024). Distances between any two CTs were at least 250 m, covering an area of 28.6 km². We selected CT locations to stratify sampling of closed and open vegetation across the study site. We attached CTs to large trees, 30-90 cm above the ground, following recommendations for camera trapping of small- and medium-sized mammals (Rowcliffe and Carbone, 2008; Ortmann and Johnson, 2021). To maximize capture probability, we deployed CTs primarily along trails, commonly utilized by terrestrial vertebrates (Rovero et al., 2010; Cusack et al., 2015). To reduce the likelihood of burned cameras and increase the likelihood of species identification by later video coders, we manually trimmed grass within 3 m of every camera 1-2 months before fires were generally detected each year. All CTs were set to video mode (video duration: day = 60 s; night = 15 s) with a 1 s delay between exposures and visited once a month to retrieve SD cards and change batteries. We manually identified cattle and all primate species.

ANALYSES

We conducted all analyses in R Studio (Version 4.4.1), assessing cattle and primate presence with Spearman's Rank correlation of the number of videos per month and chi square tests of the number of videos per season and vegetation type to investigate the effect of season and vegetation on species presence. We collapsed all signs of pastoralists (including domestic dogs, herders, and cattle) into the term 'cattle' for the purposes of this analysis. For temporal analyses and to address the possibility of animals foraging for extended periods in front of camera, we collapsed videos that were recorded within the same hour block into single observations. The number of videos recorded per hour across each taxonomic group was highly variable (Table A1 in the Appendix).

Results

We analysed 3324 videos, with coverage in woodland (n = 4 cameras), riparian (3), grassland (4), and rocky outcrop (2) vegetation. The dataset included 838 videos of cattle, 221 of diurnal primates, and 40 videos of large predators (including leopard and hyena; Table 2). Three cameras recorded cattle only, five recorded primates only, and five cameras recorded evidence of both primates and cattle.



Figure 2. (A) The proportion of observations of cattle and primates was not significantly correlated. (B) Proportion of observations of cattle and primates varied across the year, with cattle seen during the dry season primarily from May to October.

We documented baboons on four of these 'copresence' cameras and vervets on two of the five co-presence cameras. Chimpanzees were not recorded on the same cameras as cattle, and no cameras recorded red-tailed, blue, or red colobus monkeys.

Overall, we found no relationship between primate and cattle presence over time (Figure 2; Spearmans rank correlation, $r^2 = 0.49$, n =12, p = 0.1). Cattle were primarily recorded during the dry season between May and October (92% of observations), whereas primates were observed more frequently on cameras during the late dry/early wet and late wet season (Figure 2; $\chi^2 = 93.4$ with Yates correction, df = 1, N =1059, p < 0.0001).

There was a significant effect of vegetation on cattle compared to primate presence. Primates were observed significantly more in closed vegetation despite being observed in both closed and open vegetation types, whilst cattle were never observed in closed vegetation $(\chi^2 = 408.84$ with Yates correction, df = 1, N = 1059, p < 0.0001). Specifically, there was significant variation in how often different primate species were recorded across vegetation types ($\chi^2 = 1323.6$, df = 9, N = 1059, p < 0.0001; Figure 3). Chimpanzees exhibited almost no overlap with cattle as they were recorded primarily in closed vegetation, whilst baboons exhibited the most overlap given their use of both grassland (10%) and woodland

(31%) vegetation, where cattle were also most frequently observed. Vervets were recorded primarily in rocky outcrop vegetation (72%) and overlapped with cattle in grasslands (20%; Figure 3).

Finally, we investigated whether temporally, primate presence on cameras where cattle were also present differed from cameras where cattle were absent (Figure 4). Cattle activity peaked between 11-15 h. When we compared primate activity in these two contexts, primate presence followed a similar, dual-peak pattern to cattle in cameras where they were both observed, compared to a temporally wider distribution of activity that peaked at dawn (approx. 0700 h) and dusk (approx. 1800 h) on cameras where cattle were not observed (Figure 4).

Discussion

Using CT data, we observed multiple areas of co-use by cattle and primates in the Issa Valley. The extent to which cattle and primates overlapped depended on multiple factors, namely primate species (we found no overlap with red colobus, blue and red-tailed monkeys or chimpanzees, for example, only yellow baboons and vervet monkeys), locomotion, and vegetation type. Guenons and colobines are characterized as arboreal taxa (Oates and Whitesides, 1990)and were thus less likely to be captured on the Issa CTs. They are also predominantly



Figure 3. Primates and cattle were both recorded across vegetation classes, but cattle were predominantly seen in open (grassland and woodland), compared to primates, which exhibited more variable distribution.



Figure 4. Proportion of primate observations over time on cameras with no cattle (solid line) and cattle (dotted line) against the background cattle rate (proportion of observations of cattle over time).

forest-dwelling, whereas cattle primarily used grassland and woodland vegetation.

Camera co-use events were dominated by dry-season overlap, when most cattle observations occurred. Wherever they have been studied, herders follow seasonally abundant forage for cattle and thus adjust grazing land use with regionally specific environmental patterns (Coppolillo, 2000). Accordingly, we predicted and found higher encounter rates during the dry season, when the only remaining forage are found in seasonally inundated grasslands. Primates, in contrast, were observed equally in wet and dry seasons across CTs. Future studies should incorporate primate feeding sources and available fruit across seasons to investigate whether primates could shift ranging to avoid cattle in the dry season, or whether they are restricted to areas where cattle are present because of the feeding tree distribution.

It is possible that other sources of variation explain the resulting patterns. For example, we did not conduct tests on inter-camera variation in detection sensitivity, detection range, etc. As such, we acknowledge that camera type could explain some of the variation. Future studies – with larger data sets – could model detection and include camera type as a random effect to control for possible differences in trigger speed or detection zone for example.

Predator presence may also have differentially affected species presence. For example, leopards (Panthera pardus) are known predators of monkeys and chimpanzees (Boesch, 1991) and also cattle (Khorozyan et al., 2018). At Issa, researchers have observed successful leopard predation on baboons and also of chimpanzees predating both red-tailed monkeys and baboons (Piel and Stewart, pers. obs.). Moreover, red-tailed monkeys experience spatially explicit landscapes of fear that impact movement (Fornof et al., 2023) and it is possible that baboons and chimpanzees respond similarly to perceived predation risk, influencing their CT encounter rates. More camera data are necessary to determine any direct relationship between primate and predator presence as observations of large predators were relatively few. However, large predators were observed

There are a multitude of ways that we can improve future investigations into cattleprimate spatial overlap. Increasing the sample size to examine inter-annual variations, identifying the location and monitoring phenology of feeding trees near CTs, and by assessing forage abundance will all add complementary data that inform movement of these species. Moreover, herd size may also be a factor in land use, as smaller herds are likely to repeatedly use areas, compared to larger herds which will more quickly exhaust it (Coppolillo, 2000).

IS CATTLE PRESENCE A RISK TO PRIMATES?

The impact of cattle on primates is not well understood, although likely parallels what is seen in non-primate wildlife, where land degradation and disease are the primary threats (Tomley, Shirley, 2009). In primates, there is growing evidence of livestock serving as vectors for disease transmission to wild primate populations (Parsons et al., 2015; Obanda et al., 2019), and in western Tanzania, indirect evidence of the impact on disturbance (including livestock presence) on primate parasite infection (e.g., baboons (Papio cynocephalus); vervet monkeys (Chlorocebus pygerythrus) Mason et al., 2022). Far more research into primate and especially livestock parasite types, diversity, and abundance are critical to assess whether cattleprimate co-habitation leads to co-infection.

We found the opposite pattern to what we expected regarding any shifting of diel behaviour in response to cattle presence, with primate and cattle occurrence mirroring each other where they were documented on the same CTs, compared to non-overlapping areas, where primate activity began earlier and ended later in the day. It may be that there is finer-level spatial segregation happening, with each CT hosting different species on an hourly level, like what has been shown in Mediterranean ungulates (Zanni et al., 2021). It could also be the case that there is limited behavioural flexibility in these groups due to territorial boundaries or else fidelity to specific feeding sources. Further analysis on a larger data set, incorporating both

spatial and temporal data simultaneously could help tease these factors apart.

Our preliminary results demonstrate spatial overlap between cattle and especially baboons and vervet monkeys, but no indications of aversion by primates (Frid and Dill, 2002). As forest-specialists, red colobus, blue, and redtailed monkeys spend most of their time in areas where cattle do not forage or range, and we found no evidence of co-use between chimpanzees and cattle, despite observed encounters between the two species recently described from Issa (Fryns et al., 2021). For now, disease transmission, the threat of domestic dogs (Waters et al., 2017), and the felling of trees to build corrals for cattle (Piel and Stewart, pers. obs) likely represent the primary threats to Issa's primates from a growing cattle presence in the study area.

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Author contributions

I.M., A.P., and F.S. designed the research. I.M. led field data collection and I.M. and A.P. collected data from videos. A.P., F.S., D.S., and I.M. wrote the manuscript.

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or

financial relationships that could be construed as a potential conflict of interest.

Data availability statement

All data analysed for this study are available in the Appendix.

Statement of ethics

This work was conducted under all necessary research permits (COSTECH research permit no. 2023-600-NA-2020-259) and with permission from the Tanganyika District local authorities.

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	5		1 1	1 1		
Hour of day	Baboon	Cattle	Chimpanzee	Vervet	Total	
07:00-07:59		8	9		17	
08:00-08:59	4		8		12	
09:00-09:59	2	4			6	
10:00-10:59	10	22			32	
11:00-11:59	2	94	3		99	
12:00-12:59	6	112	3		121	
13:00-13:59	4	78	8	2	92	
14:00-14:59	8	90	6		104	
15:00-15:59	26	97	5	6	134	
16:00-16:59		54	6		60	
17:00-17:59	5	35	3	8	51	
18:00-18:59	15	6		7	28	
19:00-19:59		28			28	
20:00-20:59						
21:00-21:59						
22:00-22:59						
23:00-23:59		1			1	
01:00-01:59		15	1		16	
02:00-02:59		27		2	29	
03:00-03:59		12			12	
04:00-04:59						
05:00-05:59						
06:00-06:59			1		1	
Total	82	684	53	25	844 ¹	

Table A1. Summary of the hourly breakdown of camera trap captures of cattle and each primate species.

¹Due to camera setting malfunction time-stamps were unavailable for some videos limiting the sample size of this analysis.