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RESEARCH ARTICLE

Assessing the Impact of Human Presence on Mammal Distributions Within a Community Conservation Area in East Africa

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ABSTRACT

Community conservation areas offer an alternative to land management in East African countries by employing governance strategies that transition decision-making from state- to community-controlled processes emphasising the rights of local people. Because this conservation model embraces local livelihoods, research is needed to examine how common forms of human presence found within community conservation areas impact local biodiversity. To test how these anthropogenic stressors affect the distribution of a wide range of mammal species, we present results from the first systematic camera trap survey conducted at Ipole Wildlife Management Area (WMA) in the Sikonge District of Tanzania. Between July and November 2022, we placed camera traps throughout the WMA to quantify the diversity of the mammal community and examine how mixed-intensity forms of anthropogenic presence, such as villages, roads, trails, and detections of human activities, correlate with mammal occupancy. We also assessed how the Koga/Ugalla River and vegetation structure influence mammal occupancy during the dry season. In total, we detected 49 wild mammal species. Using multi-species spatial occupancy models for 39 species with sufficient observations, we found that mammal occupancy across the full community was positively correlated with proximity to roads, trails, and water and negatively correlated with village proximity. Our results demonstrate that signs of human presence within community conservation areas can impact mammal distributions, highlighting the need to account for anthropogenic features when managing biodiversity in such landscapes.

1 | Introduction

Community-managed conservation areas represent a transition from state-controlled to community-controlled wildlife management regimes and can be viewed as an alternative to “top-down” conservation approaches that tend to exclude local people from land management (Kiwango et al. 2018). This approach promotes wildlife diversity while supporting local activities inside conservation areas and involves communities that often suffer from great poverty (Salerno et al. 2016). However, this type of management strategy has been criticised when wildlife management areas take an overly strict approach regarding land management with little consideration for people's livelihoods (Hutton et al. 2005). This is a particular issue when WMAs prioritise wildlife conservation, at the expense of farmers and living spaces, thereby neglecting the social and human aspects of this management strategy (Bluwstein et al. 2016; Moyo et al. 2016).

WMAs are a specific form of community-based conservation focused primarily on the management of wildlife species of ecological and economic value. Ideally, residents of member villages benefit financially through the sustainable use of natural resources, while the careful regulation of hunting and poaching helps to reduce negative impacts on wildlife populations (Makupa 2013).

Effective community-based conservation is essential for the stability of wildlife populations, but it depends heavily on the engagement and collective action of local communities, as well as on the tangible benefits it provides (Ogutu et al. 2017). As a result, the efficiency of WMAs in protecting wildlife can vary, particularly because anthropogenic activities are often present in the surrounding areas and sometimes even within the conservancy. Increased human densities that may lead wildlife to reduce their use of protected areas (Janis and Clark 2002; Ogutu et al. 2017).

In this context, assessing the ecological effectiveness of WMAs is crucial to ensure that they fulfil their dual role: promoting community inclusion in decision-making processes and providing a sanctuary where wildlife populations can thrive. However, such assessments are often limited by insufficient resources, capacity, and appropriate methodologies. Within the scientific community, relatively few studies have examined the potential anthropogenic pressures associated with this management strategy (Krausman et al. 2009; Knapp 2012) or evaluated its overall ecological effectiveness (Lee 2018a, 2018b; Lee and Bond 2018; Kiffner et al. 2020).

The close proximity of WMAs to villages, along with the ease of access via roads and trails, may make them more vulnerable to illegal activities such as poaching and intensive livestock herding (Rogan et al. 2017). Consequently, WMAs may experience greater anthropogenic pressure than more strictly regulated protected areas, potentially affecting the density and spatial distribution of wildlife populations (Drouilly et al. 2018; Easter et al. 2019; Tucker et al. 2020). This issue is likely to intensify over time as human populations grow, along with associated disturbances such as agricultural expansion, livestock grazing, bushmeat hunting, and retaliatory killing of predators (Riggio et al. 2018).

Human land-use activities, especially those linked to agriculture, are widely recognised as major drivers of biodiversity loss through habitat degradation, fragmentation, and conversion (Clements et al. 2014; Drouilly et al. 2018; Easter et al. 2019). Numerous studies have documented the effects of village proximity on mammal occupancy, often reporting reduced wildlife presence near settlements (Easter et al. 2019; Giliba et al. 2024). However, other studies report neutral or even opposite trends, with some species showing no response or increased presence in non-protected areas (Drouilly et al. 2018; Tucker et al. 2020). Land use therefore plays a significant role in shaping species distributions, but its impacts can be complex, as species-specific responses vary widely depending on the study system and methodology (Rich et al. 2016; Drouilly et al. 2018; Easter et al. 2019; Tucker et al. 2020; Giliba et al. 2024).

More specifically, animals may perceive humans as predators and adjust their behaviour in ways that alter their spatial use of the landscape (Smit 2023). Increased human proximity can influence mammals at both spatial and temporal scales, for example, causing typically diurnal species to become more nocturnal in heavily managed areas (Gaynor et al. 2018) or prompting wildlife to avoid human-dominated landscapes altogether (Easter et al. 2019).

Although several studies have implied that WMAs can host high levels of biodiversity, sometimes similar to national parks, most of these studies have relied exclusively on transect counts, which have been recognised to bias detection towards large-bodied diurnal species (Silveira et al. 2003; Lee 2018a, 2018b; Lee and Bond 2018; Kiffner et al. 2020, Steinbeiser et al. 2019; Moore et al. 2020). Incorporating survey approaches that reduce such biases while limiting disturbances on wildlife, such as camera trapping, is essential to demonstrate the relative ecological value that WMAs might provide (Silveira et al. 2003).

In this study, we assess the status of a terrestrial mammal community in the Ipole WMA, Tanzania. At 24 years since creation, Ipole is one of the oldest of the 21 WMAs currently established in the country and provides an important case study given that nineteen additional community conservation areas are planned for the future that will collectively cover 7% of Tanzania's surface area (Lee 2018a, 2018b). Using camera trap surveys to systematically assess the mammal community, we address two conservation-relevant questions: (1) What is the species richness within the WMA? (2) How do anthropogenic and environmental variables correlate with variation in species-specific occupancy and overall community occupancy?

Specifically, we expect roads and trails to act as attractants for carnivorous species (Burton et al. 2015; Kautz et al. 2021; Rich et al. 2017; Zurkinden 2017), and for the overall community to be repelled by villages (Easter et al. 2019; Barker et al. 2023). However, we anticipate species documented to benefit from human presence (e.g., spotted hyaenas, lions, bushpigs, elephants, vervet monkeys, yellow baboons) to be attracted to settlements (Strinning 2006; Kwaslema et al. 2017).

1.1 | Study Area

Ipole WMA has been designated as a WMA since 2002 and formally delineated in 2006 (Keraryo 2015). It is an unfenced community wildlife conservation area in the Ugalla ecosystem, located near the village of Ipole in the Sikonge district of Tabora (Severre 2014). The Wildlife Management Area is bordered by: Ipole, Ugunda, Mwamulu, Msuva, Idekamiso and Utimule villages, Ipembambazi Forest Reserve, Itulu Hills Nature Reserve to the east; Ugalla Game Reserve to the west; Inyonga Gamer Reserve to the south; and Walla Forest Reserve, Udongo and Makazi villages to the north (Keraryo 2015). It lies in the vicinity of other surveyed sites (e.g., Mlele (Game Controlled Areas), Rungwa River (Game Reserves), Kululu (Village land Forest Reserve), and Rukwa (Game Reserve)) and could act as a corridor for seasonal migrating species with large territory ranges, such as the African elephant (*Loxodonta africana*) and the African wild dog (*Lycaon pictus*) that are both detected on a yearly basis at other monitored sites in the region (Bloesch 2019; Villard 2022).

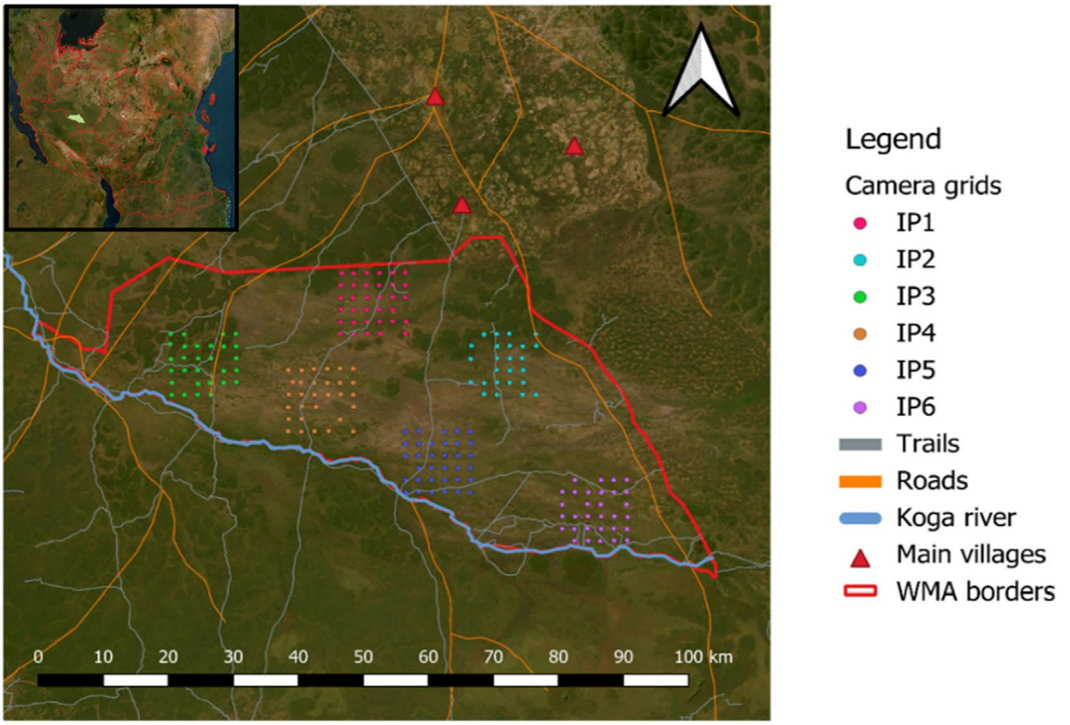

FIGURE 1 | Map of Ipole WMA, Tanzania (2022), showing the 183 camera trap locations used for analysis. Six grids were deployed across the landscape, each originally intended to hold 36 camera traps. However, not all cameras were used due to technical issues such as battery failure or insufficient SD card storage.

Natural resource use is managed by JUHIWAI (Jumuiya ya Hifadhi ya Wanyama Pori Ipole), an authorised community conservation association, which recruits, trains and equips villages game scouts (VGS) to conduct monitoring and law enforcement patrols in the WMA (Severre 2014). JUHIWAI is composed of representatives from 8 villages (Utimule, Msuya, Idekamiso, Mwamulu, Ipole, Ugunda, Makazi and Udongo) and receives external support from numerous institutions.

Management regulations permit low-intensity multiple-use practices, including tourism hunting (Strinning 2006), photography tourism, fishing, logging, and beekeeping (Severre 2014). While these practices are regulated and enforced by JUHIWAI, Sikonge District, Tanzania Forest Services Agency (TFS), and Tanzania Wildlife Management Authority (TAWA), infractions still occur, including illegal logging within the core area of the reserve, poaching, and livestock grazing (Severre 2014; Keraryo 2015). Such illegal activities may be partly driven by the ease of access to villages bordering the reserve and a lack of law enforcement. Ipole WMA faces further challenges due to confusion over the administrative status of the reserve. It is managed concurrently as a WMA, a game controlled area, and a forest reserve, which complicates efforts to enact and maintain consistent management procedures (Severre 2014; Keraryo 2015). Revenue from tourism, related activities, and other natural resources in the WMA can play an important role in the socio-economic development efforts of the local communities from the surrounding member villages (Keraryo 2015). However, the WMA is at risk from environmental degradation arising from unsustainable resource exploitation and ecologically negative activities associated with the influx of illegal livestock into the WMA (Keraryo 2015). The root causes of these problems have been reported to be linked to poverty, poor land use, overstocking, and unsustainable farming systems (Keraryo 2015).

Ipole WMA represents a mixture of dry and wet open miombo woodland with an annual average rainfall of 1000 mm (Bloesch 2020). Seasonal flooding events (November–May) submerge up to 20% of the WMA and the permanent river is Koga (named Ugalla once it leaves Ipole WMA) (Keraryo 2015). The area of the WMA covers 2540 km^2 (Severre 2014; Keraryo 2015). Upland vegetation consists of woodland, thickets, and grassland while lowland or wetland vegetation consists of wooded grassland and swamps (Keraryo 2015).

2 | Materials and Methods

We sampled six 100 km^2 grids within the Ipole WMA (in the former Iswangala Forest Reserve), covering a total of 600 km^2 (Figure 1). Grids were positioned to (1) sample all major habitats found within the WMA, (2) maintain logistical access for researchers and VGS, and (3) maintain comparability among similar monitoring studies currently occurring in the region (Fischer et al. 2013; Hausser et al. 2017; Villard 2022).

Camera trapping is widely used to study mammal distributions and community patterns throughout the world, particularly in Africa (Hausser et al. 2017; Cavada et al. 2019; Williams et al. 2021). Regarding performance in species detectability targeted towards mammalian species, it has been proven to be the most effective method compared to other approaches such as visual-based transects, opportunistic encounters, car-transects, or acoustic sensors (Roberts 2011; Hausser et al. 2017; Zwerts et al. 2021).

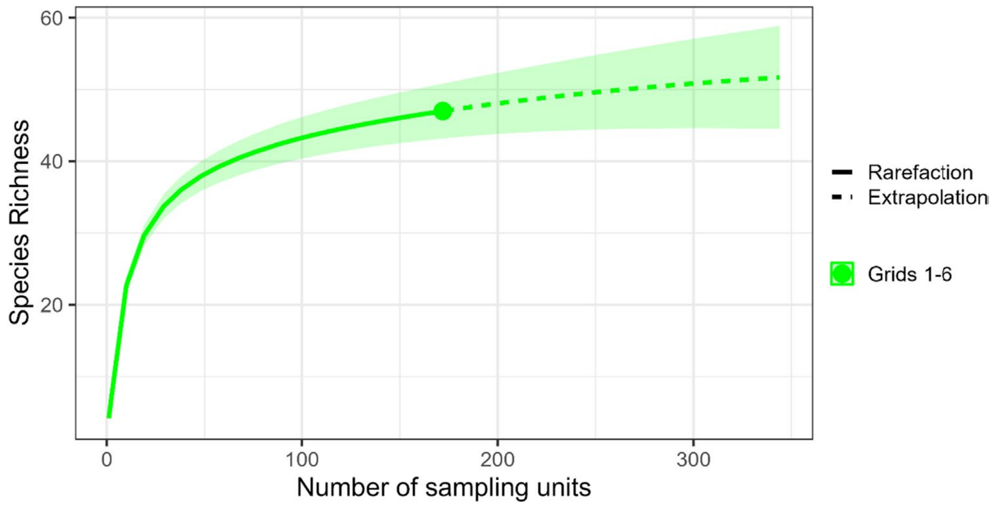

FIGURE 2 | Species accumulation curve across the 6 grids consisting of 183 camera traps. Sample coverage (SC) was 99.05877% with 49 observed wild species across 183 sites. The solid line represents the observed data, the dotted line represents the extrapolation curve, the dot stands for the total number of observed species, and the band is the 95% confidence interval.

We set up a total of 216 camera traps across the six grids, with cameras placed every 2 km within each grid (36 cameras per grid; Figure S1). A grid mesh of 2 × 2 km was selected to ensure independence between cameras (Rovero and Zimmermann 2017) and maximise detections of a wide variety of species of varying territory sizes. This sampling design has also been shown to be effective in past studies conducted in the region (Fischer et al. 2013; Buffard 2018; Villard 2022). Cameras were set to burst mode with an interval of 1 min between each trigger and an intermediate sensitivity to increase the probability of detecting an animal while reducing the chance of being triggered by wind or vegetation. At each grid location, we placed cameras randomly on trees at approximately 1.20 m to minimise wildlife related damages and within 100 m of animal tracks and systematically cut the vegetation to increase detection probability.

We sampled grids during the dry season of 2022 (beginning of May through end of October), with half sampled in July–August and the remainder sampled in September–October. Cameras were operated for approximately 1 month during each survey session. The different sampling dates likely did not produce biases because all sampling occurred during the dry season when mammals are generally less nomadic due to reliance on fixed key resources (Vesey-FitzGerald 1960; Birkett et al. 2012).

2.1 | Analysis

2.1.1 | Species Richness

All analyses were conducted using R version 4.1.2 (R core development team 2018). We pooled all data from camera trap surveys to create a list of all mammal species detected within the WMA. We assessed our sampling effort by (1) calculating the sample coverage across all camera sites using the function "iNEXT" (function 'iNEXT()' in 'iNEXT-package' version 3.0.1; Hsieh et al. 2022; Figure 2), (2) creating a species accumulation curve based on camera trap days using the function "specaccum" (function 'specaccum()' in 'vegan-package' version 2.6.10; Oksanen et al. 2001; Figure S2), and (3) calculating the number of trap nights for each grid Figure S3; trap effort totalled 4884 trap-nights (IP1: 834; IP2: 719; IP3: 738; IP4: 685; IP5: 1053; IP6: 855).

2.1.2 | Occupancy Modelling

We processed photos using Lepus (Huber, 2018. Lepus [Online Software] Version 4.2.); only images with animals identified to species level were used. Images were then divided into four separate weeks, and each week was treated as a repeat visit (Rovero and Zimmermann 2017). We restricted our modelling of occupancy to (1) species detected at least three times across all cameras during the entire survey and (2) cameras operating for at least five days. This resulted in a total of 39 species with sufficient observations, including three domestic species (cattle (*Bos taurus africanus*), dogs (*Canis lupus familiaris*), goats (*Capra hircus*)) that we considered indicators for anthropogenic activity and regrouped under "Anthropogenic signs". In total, we used 183 camera trap locations for the occupancy analyses.

We used a Bayesian, multi-species spatial occupancy model that accounts for detection error when computing community-wide and species-specific occupancy estimates while controlling for spatial autocorrelation among sampling sites (function 'spMsPG0cc' in package 'Sp0ccupancy' Version 0.8.0; Doser et al. 2022). We incorporated environmental covariates (Table 1) thought to be good predictors of mammal occupancy and reported covariate beta estimates and 90% credible intervals (CI). Each covariate was standardised to a mean of 0 and unit variance. We considered a significant relationship between occupancy and a given covariate when the 90% CI of the posterior density does not overlap zero. Due to correlations among variables (Figure 3), we ran three separate models: a model including habitat covariates (open grassland vs. open woodland proportion), a model including environmental variables (Euclidian distance from roads, trails, villages and river), and a model including an anthropogenic variable (Euclidian distance from signs of anthropogenic activities detected by camera traps). We also included variables related to habitat and camera sampling effort as part

TABLE 1 | Covariates hypothesised to influence mammal occupancy.

Covariate	Data type	Prediction	Transformation	References
Distance to water	Distance of camera trap stations to the nearest water source	Mammal community occupancy will be negatively correlated with water presence	Distance to water sources calculated in meters and log-transformed. (Scaled to have a mean of 0 and SD of 1)	Lucas Villard (2022) and Cavada et al. (2019)
Distance to roads	Distance of camera trap stations to the nearest road (official main roads bordering Ipole WMA)	Mammal community occupancy will be positively correlated with roads	Distance to roads calculated in meters and log-transformed. (Scaled to have a mean of 0 and SD of 1)	Lucas Villard (2022)
Distance to trails	Distance of camera trap stations to the nearest trail (dirt trails used by motorcycles, bikes, cars and on foot)	Mammal community occupancy will be negatively correlated with trails	Distance to trails calculated in meters and log-transformed. (Scaled to have a mean of 0 and SD of 1)	Soultan et al. (2021)
Distance to villages	Distance of camera trap stations to the nearest village	Mammal community occupancy will be negatively correlated with villages	Distance to villages calculated in meters and log-transformed. (Scaled to have a mean of 0 and SD of 1)	Lucas Villard (2022) and Cavada et al. (2019)
Habitat (site level)	Habitat type (i.e., proportion of closed woodland vs. open grassland in 500 m radius around each camera trap station)	Mammal community occupancy and detection may be influenced by habitat type as it varies in productivity	Miombo forests, shrubland vegetation classes were pooled as closed woodland, and floodplains, grassland, grassed woodland were pooled as open woodland.	Lucas Villard (2022) and Cavada et al. (2019)
Distance to Anthropogenic signs	Distance of camera trap stations to the nearest Anthropogenic signs' detection	Mammal community occupancy will be negatively correlated with human presence	Distance to signs of Anthropogenic activities in meters and log-transformed. Scaled to have a mean of 0 and SD of 1	—

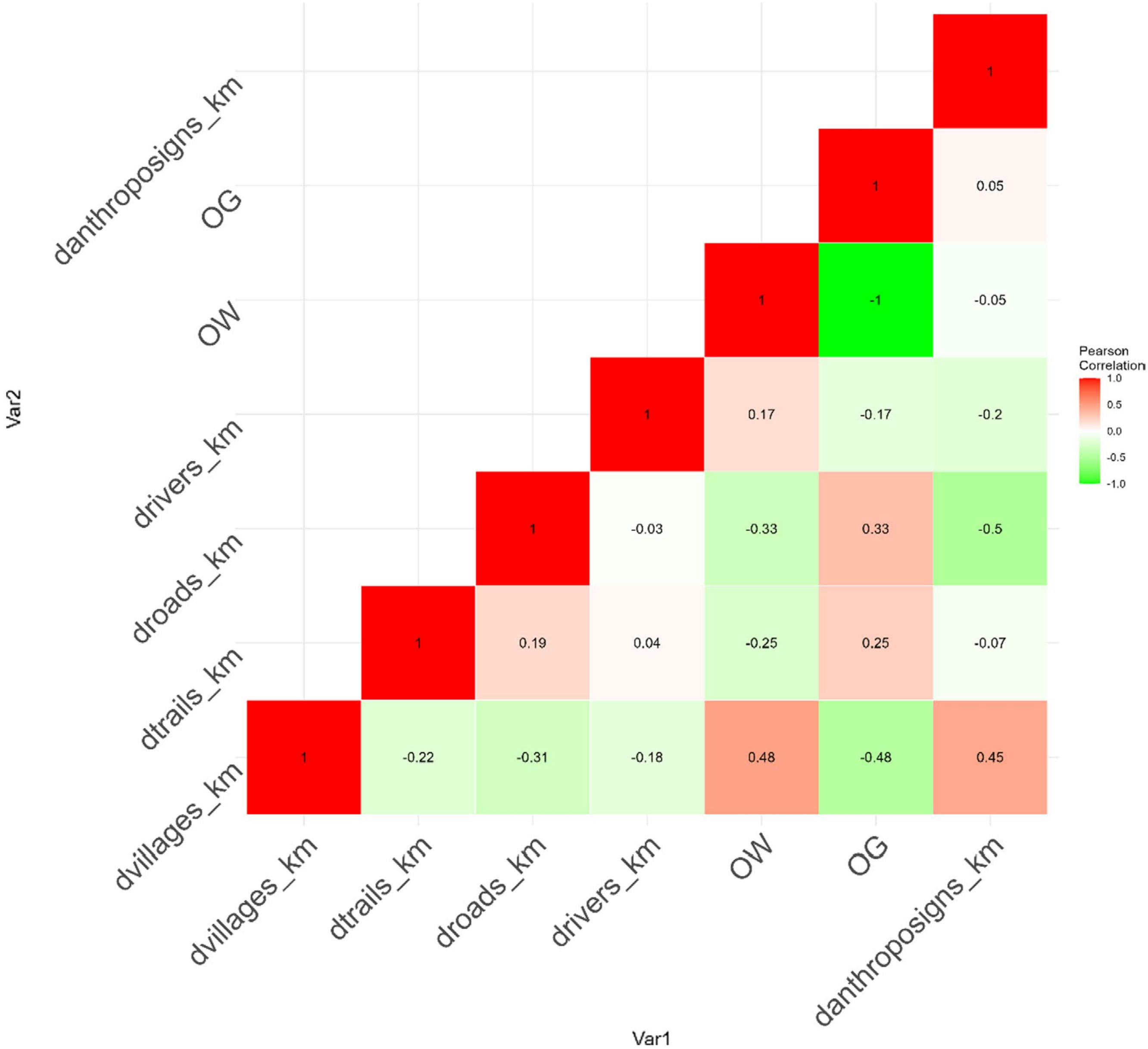

FIGURE 3 | Pearson Pairwise correlation matrix for all covariates considered in the occupancy models. Variables include Euclidian distance (in km) to the nearest river, road, trail, village and sign of anthropogenic activities (drivers_km, droads_km, dtrails_km, dvillages_km, danthroposigns_km), as well as the proportion of open grassland (OG) and open woodland (OW) within a 500 m radius around each camera trap.

of the detection component of the models. See Appendix S2 in the Supporting Information for details on model characteristics.

2.1.3 | Predicted Occupancy Maps

We calculated standardised distance rasters for covariates of interest considered relatively fixed across time: distance to water, distance to roads, distance to trails, distance to villages (Table 1) and built a stacked raster (function 'stack' in the 'raster-package' Version 3.6–31) in RStudio 2022.02.3 (Villard 2022). The mean posterior distribution (MPD) of the coefficients of each environmental covariate from the multi-species spatial occupancy model were combined with the stacked raster. We created a function "fun.psi()" that multiplies each of the stacked distance rasters by its respective MPD. This function was used to calculate predicted occupancy values at the pixel scale for each species and across the entire community (see Appendix S2 in supporting information for detailed analysis; Villard 2022).

3 | Results

3.1 | Species Richness of Mid and Large-Sized Mammals of Ipole WMA

We detected a total of 49 wild species and 3 domestic mammals regrouped under "Anthropogenic signs" (Table 2). This included 6 species on the IUCN Red List: African elephant (*Loxodonta africana*, IUCN-EN), Masai giraffe (*Giraffa c. tippelskirchi*, IUCN-EN), lion (*Panthera leo*, IUCN-VU), leopard (*Panthera pardus*, IUCN-VU), African buffalo (*Syncerus caffer*, IUCN-NT), and plains zebra (*Equus quagga*, IUCN-NT). Sample coverage (SC) was 99.05877% (Figure 2), meaning that we sufficiently

TABLE 2 | Latin names of detected mammals using camera traps with the associated number of total detections across all sites and the number of sites they were detected at. Red list status is indicated as well (the darker the cell the more threatened).

	Species latin name	Species common names	Red list status	Number of total detections	Number of detection sites
1	*Aepyceros melampus*	Impala	LC	8	7
2	*Alcelaphus b. lichtensteinii*	Lichtenstein's hartebeest	LC	23	18
3	*Bdeogale crassicauda*	Bushy-tailed mongoose	LC	8	6
4	*Chlorocebus pygerythrus*	Vervet monkey	LC	41	29
5	*Civettictis civetta*	African civet	LC	32	21
6	*Cricetomys gambianus*	Gambian pouched rat	LC	3	3
7	*Crocuta crocuta*	Spotted hyaena	LC	15	13
8	*Damaliscus l. jimela*	Topi	LC	90	39
9	*Equus quagga*	Plains zebra	NT	22	14
10	*Felis silvestris lybica*	African wildcat	LC	5	5
11	*Galago senegalensis*	Northern lesser galago	LC	2	2
12	*Genetta angolensis*	Angolan genet	LC	107	63
13	*Genetta maculata*	Rusty-spotted genet	LC	19	12
14	*Giraffa c. tippelskirchi*	Masai giraffe	VU	35	16
15	*Helogale parvula*	Dwarf mongoose	LC	3	2
16	*Herpestes ichneumon*	Egyptian mongoose	LC	2	1
17	*Herpestes sanguineus*	Slender mongoose	LC	1	1
18	*Hippotragus equinus*	Roan antelope	LC	27	21
19	*Hippotragus niger*	Sable antelope	LC	50	30
20	*Hystrix africaeaustralis*	Cape porcupine	LC	17	11
21	*Hystrix cristata*	Crested porcupine	LC	4	4
22	*Ichneumia albicauda*	White-tailed mongoose	LC	18	14
23	*Kobus ellipsiprymnus*	Waterbuck	LC	8	3
24	*Leptailurus serval*	Serval	LC	21	14
25	*Lepus victoriae*	African savanna hare	LC	30	16
26	*Loxodonta africana*	African elephant	EN	4	4
27	*Lupulella adusta*	Side-striped jackal	LC	12	8
28	*Lupulella mesomelas*	Black-backed jackal	LC	2	2
29	*Madoqua kirkii*	Kirk's dik-dik	LC	1	1
30	*Mellivora capensis*	Honey badger	LC	33	30
31	*Mungos mungo*	Banded mongoose	LC	36	25
32	*Orycteropus afer*	Aardvark	LC	11	10
33	*Ourebia ourebi*	Oribi	LC	48	28
34	*Panthera leo*	Lion	VU	1	1
35	*Panthera pardus*	Leopard	VU	4	4
36	*Papio cynocephalus*	Yellow baboon	LC	29	19

(Continues)

TABLE 2 | (Continued)

	Species latin name	Species common names	Red list status	Number of total detections	Number of detection sites
37	*Pedetes surdaster*	East African springhare	LC	9	4
38	*Petrodromus tetradactylus*	Four-toed elephant shrew	LC	6	4
39	*Phacochoerus africanus*	Common warthog	LC	71	46
40	*Potamochoerus larvatus*	Bushpig	LC	27	22
41	*Proteles cristata*	Aardwolf	LC	3	3
42	*Raphicerus sharpei*	Sharpe's Grysbok	LC	2	2
43	*Redunca arundinum*	Southern reedbuck	LC	61	26
44	*Rhynchogale melleri*	Meller's mongoose	LC	1	1
45	*Sylvicapra grimmia*	Common duiker	LC	169	76
46	*Syncerus caffer*	African buffalo	NT	17	9
47	*Tragelaphus scriptus*	Bushbuck	LC	2	1
48	*Tragelaphus strepsiceros*	Greater kudu	LC	15	12
49	*Thryonomys swinderianus*	Greater can rat	LC	1	1
50	*Anthropogenic signs*	Anthropogenic signs	LC	284	45

sampled the local mammal community in relation to our sampling effort.

3.2 | Correlates of Occupancy for Mid and Large-Sized Mammals

3.2.1 | Habitat Associations

We found no correlations between the proportion of open grassland at a camera site and occupancy at the community level ($\beta = -0.036$, 90% CI: −0.033–0.26). However, we found a significant positive correlation at the species level for the topi (*Damaliscus lunatus jimela*) ($\beta = 0.73$, 90% CI: −0.022–1.46; Figure S3) and a nearly significant negative correlation for the Yellow baboon (*Papio cynocephalus*) ($\beta = -0.829$, 90% CI: –1.86–0.0036; Figure S3).

3.2.2 | Environmental Variables and Anthropogenic Presence

We found strong positive correlations between community occupancy and distance to villages, meaning that species across the mammal community were more likely to occupy sites far from villages ($\beta = 0.20$, 90% CI: 0.03–0.38; Figure 4). At the species level, we found the same pattern for twelve species (Figure 5): African buffalo (*Syncerus caffer*), Southern reedbuck (*Redunca arundinum*), common warthog (*Phacochoerus africanus*), African savanna hare (*Lepus victoriae*), sable antelope (*Hippotragus niger*), roan antelope (*Hippotragus equinus*), Masai giraffe (*Giraffa camelopardalis tippelskirchi*), Angolan genet (*Genetta angolensis*), plains zebra (*Equus quagga*), topi (*Damaliscus lunatus jimela*), oribi (*Ourebia ourebi*), and impala (*Aepyceros melampus*). Conversely, we found strong negative correlations for the remaining variables, meaning that community occupancy was higher at sites closer to roads ($\beta = -0.15$, 90% CI: −0.31 to −0.008), trails ($\beta = -0.15$, 90% CI: −0.30 to 0.008), and the Koga/Ugalla River ($\beta = -0.29$, 90% CI: −0.43 to −0.119; Figure 4). At the species level, occupancy was higher with proximity to roads for 5 species, to trails for seven species, and to the river for eleven species (Figure 5). In general, anthropogenic signs were found closer to villages ($\beta = -0.56$, 90% CI: −0.92 to −0.21) and trails ($\beta = -0.41$, 90% CI: −0.75 to −0.05; Figure 5).

When only considering distance from detections of anthropogenic signs as an environmental covariate, occupancy at the community level was positively correlated ($\beta = 0.07$, 90% CI: 0.027–0.11), meaning that species across the community are more likely to occupy sites far from signs of anthropogenic activities (Figure 6).

3.2.3 | Detection

Probability of detection was positively correlated with the number of active camera trap days at the community level ($\beta = 0.42$, 90% CI: 0.3–0.546) and at the species level for all species (Figure S5). Detection probability increased with larger amounts of open grassland habitat around a given camera trap at the community level ($\beta = 0.14$, 90% CI: 0.021–0.25; Figure 7). At the species level, detectability significantly increased with smaller amounts of open grassland for one species, the common duiker (*Sylvicapra grimmia*) ($\beta = -0.21$, 90% CI: −0.44 to −0.008; Figure S5). Livestock detection also increased with the amount of open grassland ($\beta = 0.22$, 90% CI: 0.019–0.43; Figure S5).

3.3 | Species-Specific Responses Categories

We used results from the occupancy models and predicted occupancy maps to categorise the 38 wild species into five categories of responses to anthropogenic and environmental factors: species that avoid (1) villages and (2) signs of anthropogenic activities, species that seem to be attracted to (3) water or (4) trails and roads, and (5) species that show no specific correlation (Figures S6–S17; see Appendices S1 and S3 supporting information for a complete list of species-specific responses). When mapping across the entire community, village avoidance and water attraction are the main drivers of occupancy (Figure 8a).

4 | Discussion

Our research highlights that WMAs can host species richness at a similar level to other protected areas in the vicinity (Cusack et al. 2015; Hausser et al. 2017) and that anthropogenic presence found within community conservation areas can impact mammal distributions. We found that Ipole WMA hosts at least 49 wild mammal species (Table 2) and found evidence that mammals appear to respond to anthropogenic presence, with community occupancy declining with proximity to villages and signs of anthropogenic activities and increasing with proximity to roads and trails (Figure 4). This suggests that multiple-use practices commonly found within community conservation areas may impact the distribution of mammals in grassland and woodland ecosystems of Tanzania.

4.1 | Covariates Specific Responses

4.1.1 | Impacts of Trails and Roads

Trails and roads appeared to act as attractants at the community level (Figure 4) and for some species (Figure 5), especially prey. This attractivity could be explained partly through movement facilitation by providing flat, compacted surfaces incurring less energy expenditure (Dickson et al. 2005; Blake et al. 2017), as shown in previous studies conducted in similar habitats but generally targeted towards carnivorous species (Burton et al. 2015; Rich et al. 2017; Zurkinden 2017; Kautz et al. 2021). Within this context, we could expect prey to be more susceptible to predation if predators occur more often on roads or trails.

Given the flat topography of Ipole with its numerous human incursions, we did expect roads and trails to facilitate occupancy of carnivores (Forman and Alexander 1998). Instead, occupancy of carnivorous species largely did not significantly correlate with roads or trails (Figure 5). This could be an indication of elevated human presence that exceeds the benefits of increased prey availability on trails or roads.

Specifically, trails within the WMA may elevate mortality risk for some species given that both carnivores and herbivores are actively hunted in the region and hunters are more likely to use established trails to circulate (Strinning 2006). In response, carnivores might actively avoid trails where signs of anthropogenic activities were high (Figures 5 and 8b), consequently increasing the risk of being killed from hunters or poachers.

Concurrently, the presence of large roads bordering Ipole WMA (Figure 1) increases the risk of collisions (Caro et al. 2014; Caro 2015), a problem reported by local authorities at Ipole and documented on a regular basis by JUHIWAI and ADAP. This collision risk seems to be aggravated during dry seasons as animals were sighted closer to the WMA's borders during the camera trap setup and more willing to cross the tarmac in search of water. This attraction may be linked to artificial water pans observed along the tarmac, which were dug by road construction workers and later filled with rainwater.

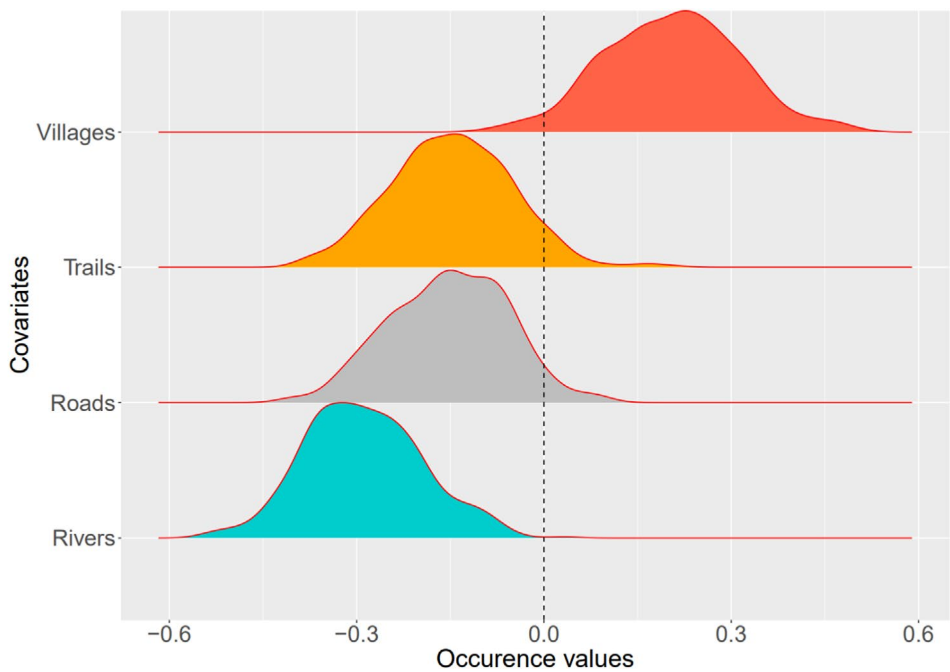

FIGURE 4 | Posterior distributions of the beta estimates representing correlations between community-level occupancy and distance to river, roads, trails and villages. The dashed line ($h = 0$) depicts the line of no-effect (above it, the correlation is positive, denoting an avoidance; below it, it is negative, denoting an attraction). The red lines indicate if > 90% of the distribution is above or below zero.

FIGURE 5 | Posterior distributions of the beta estimates representing correlations between species-level occupancy and distance to river, roads, trails and villages. The dashed line ($h = 0$) depicts the line of no-effect (above it, the correlation is positive, denoting an avoidance; below it, it is negative, denoting an attraction). The red lines indicate if > 90% of the distribution is above or below zero. The variable for "Anthropogenic signs", corresponding to signs of Anthropogenic activities, has been highlighted in red.

In this case, trails would act as areas of low predation risk (Shannon et al. 2014; Barker et al. 2023) and explain why we observed more of a positive correlation between occupancy and trails proximity among prey species while main roads could act as an ecological trap (Titeux et al. 2020) for species that seek alternative water resources during droughts.

4.1.2 | Influence of Villages

As expected, this study suggests that most mammalian species tend to avoid villages. While wild animals generally prefer to avoid contact with humans (Cavada et al. 2019), some species are associated with settlements because of access to food and lower predation risk (Strinning 2006; Møller 2012; Smith et al. 2019).

In Ipole, we expected the occupancy of certain species to increase closer to human settlements, given that some of the detected species have been documented to damage crops and attack livestock. These species include African elephants, lions, yellow baboons, vervet monkeys, greater kudus, dik-diks, African buffalos, common warthogs, bushpigs, impalas, and Cape porcupines (Strinning 2006). However, almost all species detected during this study seemed to actively avoid villages (Figure 5). This generalised avoidance could reflect the months this survey was conducted, falling as well outside the period when crops (e.g., maize, potatoes, rice or tobacco) are cultivated, between January and April.

Likewise, drier conditions facilitate human access from villages (e.g., less vegetation or water bodies to cross, and drier

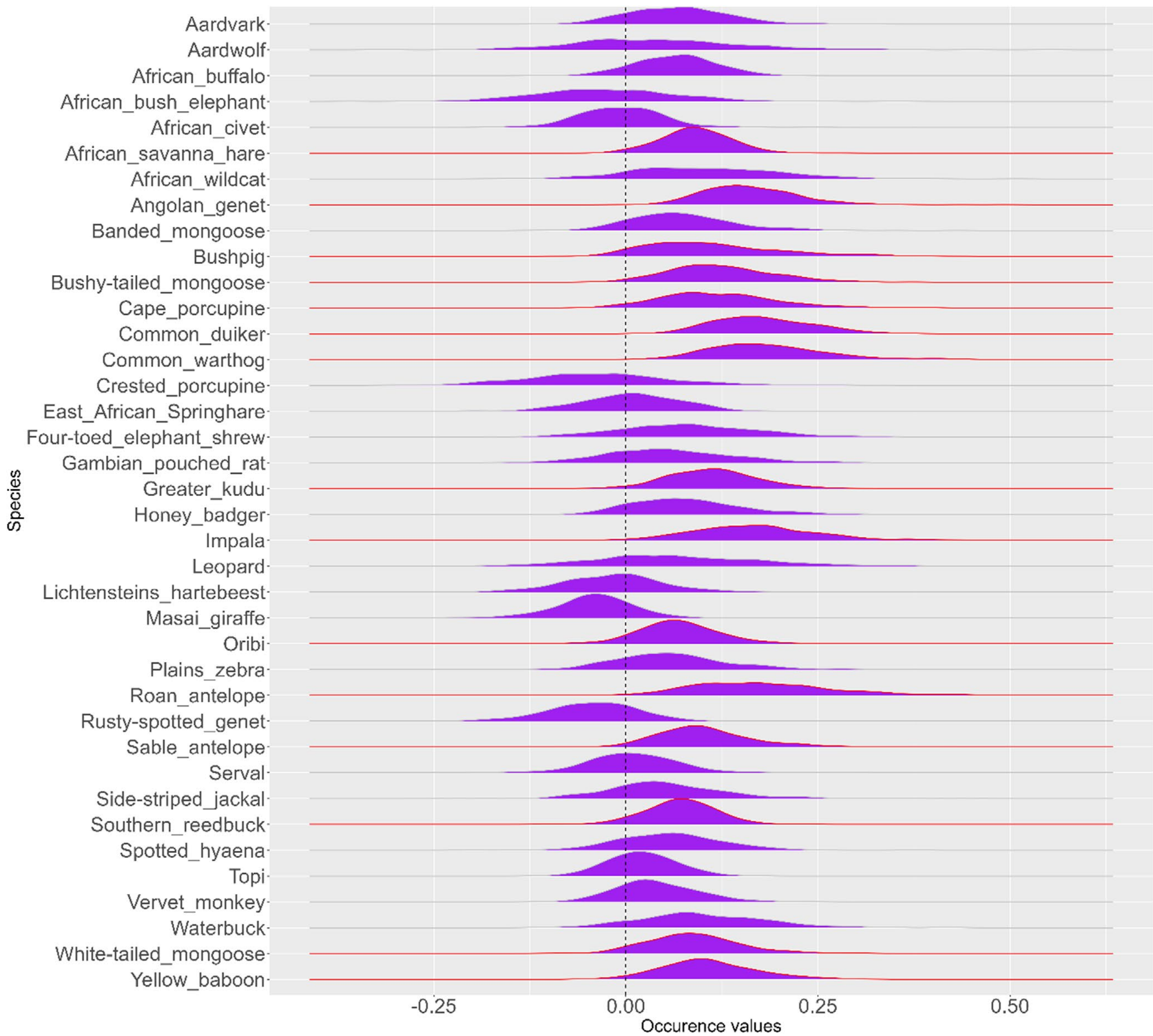

FIGURE 6 | Posterior distributions of the beta estimates representing correlations between species-level occupancy and distance to signs of anthropogenic activities (livestock, domestic dogs and human detections). The dashed line ($h = 0$) depicts the line of no-effect (above it, the correlation is positive, denoting an avoidance; below it, it is negative, denoting an attraction). The red lines indicate if > 90% of the distribution is above or under zero.

trails; Rashidi et al. 2018; William Nyahongo 2024), and potentially increase human presence within the WMA, pushing animals farther from settlements (Easter et al. 2019; Linuma et al. 2022).

Additionally, the majority of species that appear to avoid human proximity are known to be hunted for bushmeat and sport (Strinning 2006). This includes the sable antelope, the common warthog, and the Masai giraffe for which we found evidence of poaching during fieldwork (L. Novovitch, personal observation). The consistent avoidance among all species could also reflect a landscape of fear created by human presence and activities towards wildlife which decreases occupancy in the village's surroundings (Ciuti et al. 2012; Smit 2023).

4.1.3 | Anthropogenic Activities

Signs of anthropogenic activities at Ipole WMA (e.g., humans, dogs, and livestock) were strongly associated with villages' proximity and trails' proximity (Figures 5 and 8b). They were not present near main roads, potentially because people were avoiding contact with VGS or other patrols surveying the WMA (L. Novovitch, personal observation). They occurred significantly more near trails, which presumably facilitate access, and villages, where herders travel frequently to buy medicine, food, or to see their relatives.

Cattle were also detected at higher concentrations near villages (Figure 8b). This reflects other regions of Tanzania, where livestock are expanding and increasingly go hand in hand with

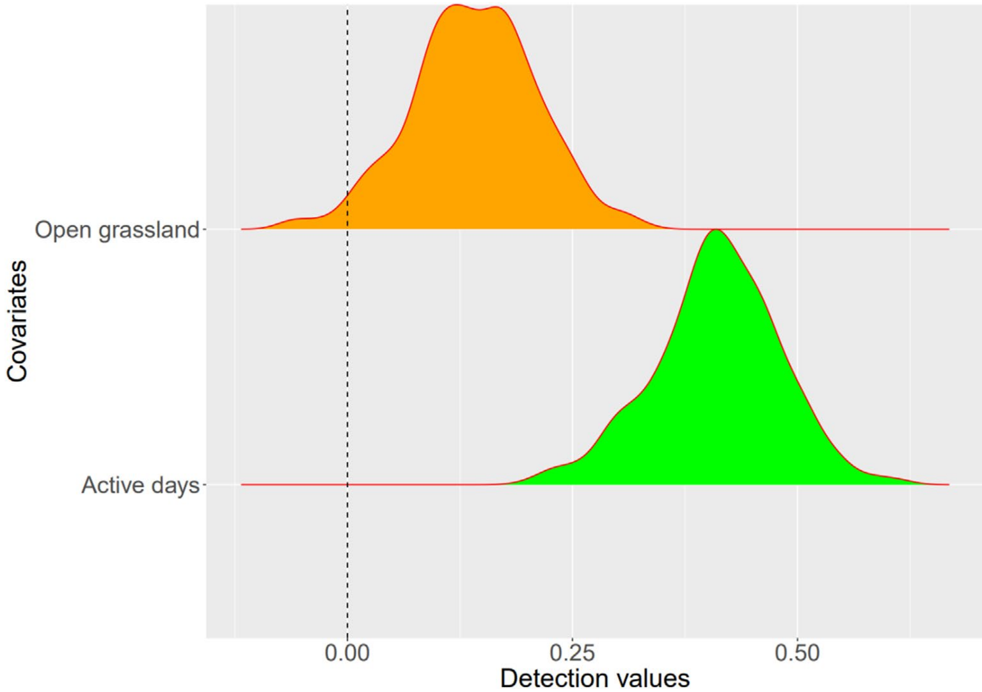

FIGURE 7 | Posterior distributions of beta estimates representing the correlation between community-level detection probabilities for the number of days a camera trap stayed active and the proportion of open grassland habitat around a camera trap site. The dashed line ($h=0$) depicts the line of no-effects (above it, the effect is positive, denoting an increase of detection with an increase of camera trap active days or an increase of open grassland proportion around a camera trap site; below it, it is negative, denoting a decrease of detection with an increase of camera trap active days or an increase of detection with a decrease of open grassland proportion around the camera trap site). The red lines indicate if > 90% of the distribution is above or below zero.

poaching as herders from some pastoralist groups actively hunt to provide for themselves and possibly kill predators to protect livestock (Heermans et al. 2021; Mrosso 2022).

Detection probability of signs of anthropogenic activities increased when cameras were set in open grassland habitat (Figure S5) given that detection probability is higher in open habitat (Figure 7) and because open grasslands provide more food resources for livestock than open woodlands. However, livestock keepers' camps were more often detected in denser vegetation during camera trap setup (Figure S18). Dense vegetation is probably a preferred camp location for two reasons: (1) decreasing the eventuality of being spotted by VGS patrols, (2) providing shade and preventing animals from overheating.

These camps were often equipped with pits, dug for access to water. These water pits could act as attractants for various species, particularly for scavengers and carnivores. We do not know to what extent livestock keepers poison carcasses to actively kill nearby carnivores in order to protect their livestock, measures that can potentially result in an ecological trap for the attracted species (Titeux et al. 2020).

When used as a covariate, most species tended to avoid signs of anthropogenic activities (Figure 6), which aligns with the general tendency of villages' avoidance (Figure 5).

4.1.4 | Water Resources

This study suggests that the Koga/Ugalla River is a general attractant for many species, which reflects a general consensus that access to water has a large impact on animal distributions in this ecosystem (Pettorelli et al. 2010; Rich et al. 2016; Cavada et al. 2019; Verschueren et al. 2021).

This ecological pattern is amplified during the dry season with fewer water bodies and harsher environments, limiting available vegetation to forage, thus reducing the amount of suitable patches with high nutritional values and driving both prey and predators to permanent water sources (Voeten et al. 2010; Boyers et al. 2019).

4.1.5 | Habitat

Our results suggest that species occupancy was generally not correlated with vegetation structure. This may be because Ipole WMA comprises only two main habitat categories: open grassland and open woodland, with gradual transitions between the two vegetation types. The WMA has a flat topography and shows little landscape fragmentation or ecological barriers, suggesting that vegetation structure may not represent an impediment to dispersal or other movements (Niebuhr et al. 2015). The relatively open landscape, composed of grasslands and woodlands without thickets or dense vegetation, may also facilitate animal movement (de Knegt et al. 2007). Consequently, species may not be constrained to a single habitat type and could be detected by visual surveys or camera traps while moving between suitable habitat patches.

4.1.6 | Study Limitations

Our study did, however, have several limitations. First, the survey was conducted over a relatively short period, therefore, the

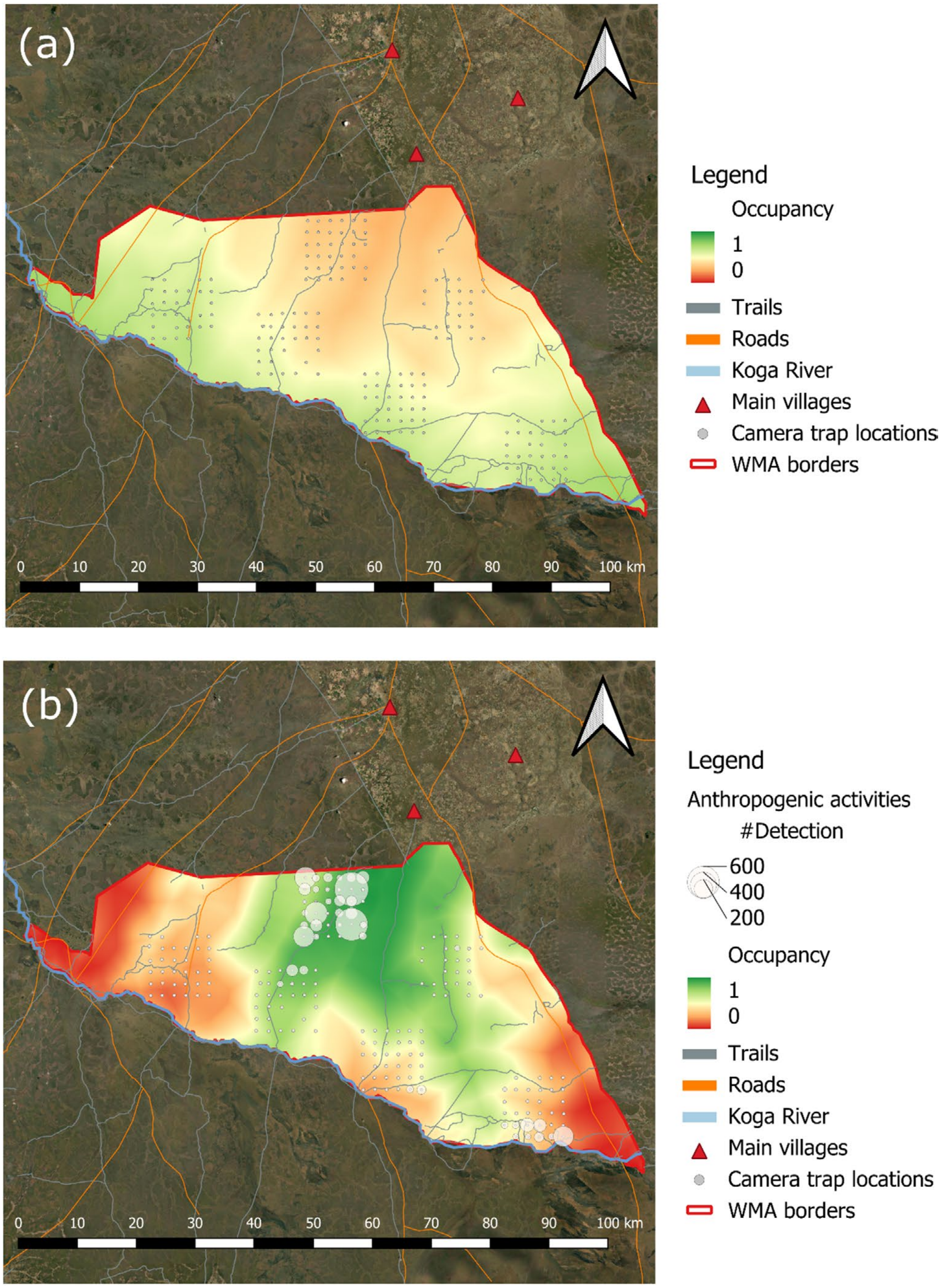

FIGURE 8 | (a) Map of predicted occupancy values for the full community of detected species, extracted from the spatial occupancy model output. Values range from 0 (high probability of unoccupied sites) to 1 (high probability of occurrence). (b) Map of predicted occupancy values for the signs of anthropogenic activities (e.g., humans, dogs, goats and cows), extracted from the spatial occupancy model output. The circles are locations where humans/livestock were detected, with the size scaled to the number of detections.

conclusions drawn from these results apply only to this timeframe and to the dry season. Second, because we included only camera-station–specific covariates, we were unable to account for species-specific measures of predation and competition, both of which are known to influence species distributions (Caro and Stoner 2003). Third, although lions (*Panthera leo*) and African wild dogs (*Lycaon pictus*) were expected to occur in the area (Strampelli et al. 2022), they could not be included in the analyses due to insufficient detections during the survey period; consequently, any conclusions concerning predators in the discussion cannot be applied to these species. Finally, the use of camera-trap detections of anthropogenic activity as a covariate may be biased, as we assumed human presence to be constant throughout the one-month survey period. In reality, it likely fluctuates as herders can move several kilometers daily in search of suitable grazing for their cattle (Maregesi et al. 2024).

5 | Conservation Outlooks

The primary objective of a community conservation area is to both contribute to wildlife and support local livelihoods while mitigating human wildlife conflicts. They should theoretically support sustainable natural resource use (e.g., beekeeping, mushroom harvesting, timbering), as well as hunting or photo tourism (Hausser and Mpuya 2004; Bloesch 2020; Kiffner et al. 2020). As villages appeared to be consistently avoided by all species in our study, their expansion at the WMA's borders could lead to a decrease in species diversity, distribution and density that might affect the development of alternative economic opportunities in the region. However, the trade-off between conservation and development remains complex. Finding effective approaches to better conserve wildlife must begin with understanding local needs and fostering collaboration with the communities living alongside these species. The key challenge that remains is to strengthen JUHIWAI's capacity to sustainably manage the area and reduce illegal activities in the long term. Trophy hunting companies operating in the WMA also bear responsibilities and possess relevant capacities; therefore, fostering more coordinated efforts among all stakeholders will be a critical first step towards improving law enforcement and limiting illegal uses in the region. The land use plans have been reviewed in 2023–2024 in order to ensure the respect of the WMA boundaries and create areas for livestock between the forest and the crops. The General Management Plan 2024–2034 demarcated different zones within the WMA (hunting, beekeeping, logging, etc.) in order to protect the areas more favourable to wildlife, avoid much human disturbances, and ease their control.

There is also a need to know more about wildlife movements within Ipole WMA and the invasion of critical habitat patches by livestock or crops. Based on our results, the Koga/Ugalla River proved to be essential for wildlife at Ipole, with occupancy increasing for almost all species near the riverbanks. Due to the WMA's direct proximity to neighbouring villages and heavily used roads, it is essential to identify and preserve wildlife corridors to facilitate the dispersal of wide-ranging species. Such measures are crucial, as wildlife persecution and road collisions continue to occur to this day. Its size, location and reliability during the dry season make it one of the main water resources of the region, and its conservation is therefore key both for people and animals. Future measures should be taken to do more patrols in this area and limit human waste and pollution that could alter water quality, from livestock herders, trophy hunting, beekeepers, and fishermen camps.

Author Contributions

Lucy H. Novovitch collected the data and led the analysis and writing of the manuscript. Yves Hausser, Sandy Mermod, and Ian Ausprey designed the methodology. Lucas Villard and Lucy H. Novovitch analysed the data. Claude Fischer contributed to data collection. All authors contributed critically to the drafts and gave final approval for publication.

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Ethics Statement

Tanzania Wildlife Research Institute Fee; Commission for Science and Technology; Residence permit class C for researcher (Permit No: 2022-508-NA-2022/161).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

This study took part in the project "Sustainable management of the Ipole WMA" of the association ADAP (Association pour le développement des Aires Protégées). The monitoring results of this study site are a subset of the yearly surveys done by ADAP that take place in various locations across western Tanzania. The donors of ADAP, therefore, reserve the right to valorise and share data themselves at a greater scale than just one location.

References

Barker, K. J., E. Cole, A. Courtemanch, et al. 2023. "Large Carnivores Avoid Humans While Prioritizing Prey Acquisition in Anthropogenic Areas." *Journal of Animal Ecology* 92, no. 4: 889–900. https://doi.org/10.1111/1365-2656.13900.

Birkett, P. J., A. T. Vanak, V. M. R. Muggeo, S. M. Ferreira, and R. Slotow. 2012. "Animal Perception of Seasonal Thresholds: Changes in Elephant Movement in Relation to Rainfall Patterns." *PLoS One* 7, no. 6: e38363. https://doi.org/10.1371/journal.pone.0038363.

Blake, J. G., D. Mosquera, B. A. Loiselle, D. Romo, and K. Swing. 2017. "Effects of Human Traffic on Use of Trails by Mammals in Lowland Forest of Eastern Ecuador." *Neotropical Biodiversity* 3, no. 1: 57–64. https://doi.org/10.1080/23766808.2017.1292756.

Bloesch, U. 2019. "Vegetation Survey of Mlele Beekeeping Zone in 2018."

Bloesch, U. 2020. "Community-Based Forest Management of the Rungwa Corridor."

Bluwstein, J., F. Moyo, and R. Kicheleri. 2016. "Austere Conservation: Understanding Conflicts Over Resource Governance in Tanzanian Wildlife Management Areas." *Conservation and Society* 14, no. 3: 218. https://doi.org/10.4103/0972-4923.191156.

Boyers, M., F. Parrini, N. Owen-Smith, B. F. N. Erasmus, and R. S. Hetem. 2019. "How Free-Ranging Ungulates With Differing Water Dependencies Cope With Seasonal Variation in Temperature and Aridity." *Conservation Physiology* 7, no. 1: coz064. https://doi.org/10.1093/conphys/coz064.

Buffard, F. 2018. "Key Determinant of the Species Richness, Distribution and Abundancy of Medium and Large Mammals in a Dry Forest Ecosystem: Environmental or Anthropogenic Factors?"

Burton, A. C., E. Neilson, D. Moreira, et al. 2015. "REVIEW: Wildlife Camera Trapping: A Review and Recommendations for Linking Surveys to Ecological Processes." *Journal of Applied Ecology* 52, no. 3: 675–685. https://doi.org/10.1111/1365-2664.12432.

Caro, T., A. Dobson, A. J. Marshall, and C. A. Peres. 2014. "Compromise Solutions Between Conservation and Road Building in the Tropics."

Current Biology 24, no. 16: R722–R725. https://doi.org/10.1016/j.cub.2014.07.007.

Caro, T. 2015. "Roads Through National Parks: A Successful Case Study." *Tropical Conservation Science* 8, no. 4: 1009–1016. https://doi.org/10.1177/194008291500800411.

Caro, T. M., and C. J. Stoner. 2003. "The Potential for Interspecific Competition Among African Carnivores." *Biological Conservation* 110, no. 1: 67–75. https://doi.org/10.1016/S0006-3207(02)00177-5.

Cavada, N., R. Worsøe Havmøller, N. Scharff, and F. Rovero. 2019. "A Landscape-Scale Assessment of Tropical Mammals Reveals the Effects of Habitat and Anthropogenic Disturbance on Community Occupancy." *PLoS One* 14, no. 4: e0215682. https://doi.org/10.1371/journal.pone.0215682.

Ciuti, S., J. M. Northrup, T. B. Muhly, et al. 2012. "Effects of Humans on Behaviour of Wildlife Exceed Those of Natural Predators in a Landscape of Fear." *PLoS One* 7, no. 11: e50611. https://doi.org/10.1371/journal.pone.0050611.

Clements, H. S., C. J. Tambling, M. W. Hayward, and G. I. H. Kerley. 2014. "An Objective Approach to Determining the Weight Ranges of Prey Preferred by and Accessible to the Five Large African Carnivores." *PLoS One* 9, no. 7: e101054. https://doi.org/10.1371/journal.pone.0101054.

Cusack, J. J., A. J. Dickman, J. M. Rowcliffe, C. Carbone, D. W. Macdonald, and T. Coulson. 2015. "Random Versus Game Trail-Based Camera Trap Placement Strategy for Monitoring Terrestrial Mammal Communities." *PLoS One* 10, no. 5: e0126373. https://doi.org/10.1371/journal.pone.0126373.

de Knegt, H. J., G. M. Hengeveld, F. van Langevelde, W. F. de Boer, and K. P. Kirkman. 2007. "Patch Density Determines Movement Patterns and Foraging Efficiency of Large Herbivores." *Behavioral Ecology* 18, no. 6: 1065–1072. https://doi.org/10.1093/beheco/arm080.

Dickson, B. G., J. S. Jenness, and P. Beier. 2005. "Influence of Vegetation, Topography, and Roads on Cougar Movement in Southern California." *Journal of Wildlife Management* 69, no. 1: 264–276. https://doi.org/10.2193/0022-541X(2005)069<0264:IOVTAR>2.0.CO;2.

Doser, J. W., A. O. Finley, M. Kéry, and E. F. Zipkin. 2022. "spOccupancy: An R Package for Single-Species, Multi-Species, and Integrated Spatial Occupancy Models." *Methods in Ecology and Evolution* 13: 1670–1678.

Drouilly, M., A. Clark, and M. J. O'Riain. 2018. "Multi-Species Occupancy Modelling of Mammal and Ground Bird Communities in Rangeland in the Karoo: A Case for Dryland Systems Globally." *Biological Conservation* 224: 16–25. https://doi.org/10.1016/j.biocon.2018.05.013.

Easter, T., P. Bouley, and N. Carter. 2019. "Opportunities for Biodiversity Conservation Outside of Gorongosa National Park, Mozambique: A Multispecies Approach." *Biological Conservation* 232: 217–227. https://doi.org/10.1016/j.biocon.2019.02.007.

Fischer, C., R. Tagand, and Y. Hausser. 2013. "Diversity and Distribution of Small Carnivores in a Miombo Woodland Within the Katavi Region, Western Tanzania." *Small Carnivore Conservation* 48: 7.

Forman, R. T. T., and L. E. Alexander. 1998. "Roads and Their Major Ecological Effects." *Annual Review of Ecology and Systematics* 29, no. 1: 207–231. https://doi.org/10.1146/annurev.ecolsys.29.1.207.

Gaynor, K. M., C. E. Hojnowski, N. H. Carter, and J. S. Brashares. 2018. "The Influence of Human Disturbance on Wildlife Nocturnality." *Science* 360, no. 6394: 1232–1235. https://doi.org/10.1126/science.aar7121.

Giliba, R. A., C. Kiffner, P. Fust, and J. Loos. 2024. "Using Density Surface Models to Assess the Ecological Effectiveness of a Protected Area Network in Tanzania." *Ecosphere* 15, no. 4: e4840. https://doi.org/10.1002/ecs2.4840.

Hausser, Y., and P. Mpuya. 2004. Beekeeping in Tanzania: When the Bees Get Out of the Woods… An Innovative Cross-Sectoral Approach to Community-Based Natural Resource Management.

Hausser, Y., R. Tagand, E. Vimercati, S. Mermod, and C. Fischer. 2017. "Comparing Survey Methods to Assess the Conservation Value of a Community-Managed Protected Area in Western Tanzania." *African Journal of Ecology* 55, no. 1: 1–11. https://doi.org/10.1111/aje.12301.

Heermans, B., J. Van Rooyen, R. Fynn, D. Biggs, M. Lewis, and J. McNutt. 2021. "Husbandry and Herding: A Community-Based Approach to Addressing Illegal Wildlife Trade in Northern Botswana." *Frontiers in Conservation Science* 2: 675493. https://doi.org/10.3389/fcosc.2021.675493.

Hsieh, T. C., K. H. Ma, and A. Chao. 2022. "Interpolation and Extrapolation for Species Diversity." http://chao.stat.nthu.edu.tw/wordpress/software_download/.

Hutton, J., W. M. Adams, and J. C. Murombedzi. 2005. "Back to the Barriers? Changing Narratives in Biodiversity Conservation." *Forum for Development Studies* 32: 341–370. https://doi.org/10.1080/08039410.2005.9666319.

Janis, M. W., and J. D. Clark. 2002. "Responses of Florida Panthers to Recreational Deer and Hog Hunting." *Journal of Wildlife Management* 66, no. 3: 839. https://doi.org/10.2307/3803148.

Kautz, T. M., N. L. Fowler, T. R. Petroelje, D. E. Beyer, N. J. Svoboda, and J. L. Belant. 2021. "Large Carnivore Response to Human Road Use Suggests a Landscape of Coexistence." *Global Ecology and Conservation* 30: e01772. https://doi.org/10.1016/j.gecco.2021.e01772.

Keraryo, H. W. 2015. "Ipole Wildlife Management Area (WMA) *General Management Plan* [General Management Plan]."

Kiffner, C., S. Thomas, T. Speaker, et al. 2020. "Community-Based Wildlife Management Area Supports Similar Mammal Species Richness and Densities Compared to a National Park." *Ecology and Evolution* 10, no. 1: 480–492. https://doi.org/10.1002/ece3.5916.

Kiwango, W. A., H. C. Komakech, T. M. C. Tarimo, and L. Martz. 2018. "Levels of Community Participation and Satisfaction With Decentralized Wildlife Management in Idodi-Pawaga Wildlife Management Area, Tanzania." *International Journal of Sustainable Development and World Ecology* 25, no. 3: 238–248. https://doi.org/10.1080/13504509.2017.1378750.

Knapp, E. J. 2012. "Why Poaching Pays: A Summary of Risks and Benefits Illegal Hunters Face in Western Serengeti, Tanzania." *Tropical Conservation Science* 5, no. 4: 434–445. https://doi.org/10.1177/194008291200500403.

Krausman, P. R., D. E. Naugle, M. R. Frisina, et al. 2009. "Livestock Grazing, Wildlife Habitat, and Rangeland Values." *Rangelands* 31, no. 5: 15–19. https://doi.org/10.2111/1551-501X-31.5.15.

Kwaslema, M. H., D. F. Robert, R. K. Jafari, and R. Eivin. 2017. "Assessing Crop and Livestock Losses Along the Rungwa-Katavi Wildlife Corridor, South-Western Tanzania." *International Journal of Biodiversity and Conservation* 9, no. 8: 273–283. https://doi.org/10.5897/IJBC2017.1116.

Lee, D. 2018a. *Community Wildlife Management Areas Are Successfully Conserving Wildlife in Tanzania*. Wild Nature Institute.

Lee, D. E., and M. L. Bond. 2018. "Quantifying the Ecological Success of a Community-Based Wildlife Conservation Area in Tanzania." *Journal of Mammalogy* 99, no. 2: 459–464. https://doi.org/10.1093/jmammal/gyy014.

Lee, D. E. 2018b. "Evaluating Conservation Effectiveness in a Tanzanian Community Wildlife Management Area: WMA Effectiveness." *Journal of Wildlife Management* 82, no. 8: 1767–1774. https://doi.org/10.1002/jwmg.21549.

Linuma, O. F., A. S. Mahenge, R. R. A. M. Mato, and A. D. Greenwood. 2022. "Drivers of Human–Wildlife Interactions in a Co-Existence

Area: A Case Study of the Ngorongoro Conservation Area, Tanzania." *Discover Sustainability* 3, no. 1: 45. https://doi.org/10.1007/s43621-022-00113-7.

Makupa, E. 2013. "Conservation Efforts and Local Livelihoods in Western Serengeti, Tanzania: *Experiences From Ikona Community Wildlife Management Area*." University of Victoria.

Maregesi, M. K., J. B. Lodin, B. J. Temu, and F. M. Mombo. 2024. "Different Groups' Grazing Technique Preferences in the Miombo Woodlands of Eastern Tanzania." *Journal of Environmental Management* 370: 122603. https://doi.org/10.1016/j.jenvman.2024.122603.

Møller, A. P. 2012. "Urban Areas as Refuges From Predators and Flight Distance of Prey." *Behavioral Ecology* 23, no. 5: 1030–1035. https://doi.org/10.1093/beheco/ars067.

Moore, J. F., W. E. Pine, F. Mulindahabi, et al. 2020. "Comparison of Species Richness and Detection Between Line Transects, Ground Camera Traps, and Arboreal Camera Traps." *Animal Conservation* 23, no. 5: 561–572. https://doi.org/10.1111/acv.12569.

Moyo, F., J. Ijumba, and J. Lund. 2016. "Failure by Design? Revisiting Tanzania's Flagship Wildlife Management Area Burunge." *Conservation and Society* 14, no. 3: 232. https://doi.org/10.4103/0972-4923.191160.

Mrosso, H. T. 2022. "Assessment of Trade Flows of Wildlife Products: The Case of Ruaha Landscape, Tanzania."

Niebuhr, B. B. S., M. E. Wosniack, M. C. Santos, et al. 2015. "Survival in Patchy Landscapes: The Interplay Between Dispersal, Habitat Loss and Fragmentation." *Scientific Reports* 5, no. 1: 11898. https://doi.org/10.1038/srep11898.

Ogutu, J. O., B. Kuloba, H.-P. Piepho, and E. Kanga. 2017. "Wildlife Population Dynamics in Human-Dominated Landscapes Under Community-Based Conservation: The Example of Nakuru Wildlife Conservancy, Kenya." *PLoS One* 12, no. 1: e0169730. https://doi.org/10.1371/journal.pone.0169730.

Oksanen, J., G. L. Simpson, F. G. Blanchet, et al. 2001. "vegan: Community Ecology Package (p. 2.7-2) [Dataset]." https://doi.org/10.32614/CRAN.package.vegan.

Pettorelli, N., A. L. Lobora, M. J. Msuha, C. Foley, and S. M. Durant. 2010. "Carnivore Biodiversity in Tanzania: Revealing the Distribution Patterns of Secretive Mammals Using Camera Traps." *Animal Conservation* 13, no. 2: 131–139. https://doi.org/10.1111/j.1469-1795.2009.00309.x.

R Core Team. 2018. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. https://www.R-project.org.

Rashidi, P., A. Skidmore, T. Wang, R. Darvishzadeh, S. Ngene, and A. Vrieling. 2018. "Assessing Trends and Seasonal Changes in Elephant Poaching Risk at the Small Area Level Using Spatio-Temporal Bayesian Modeling." *International Journal of Geographical Information Science* 32, no. 3: 622–636. https://doi.org/10.1080/13658816.2017.1404605.

Rich, L. N., C. L. Davis, Z. J. Farris, et al. 2017. "Assessing Global Patterns in Mammalian Carnivore Occupancy and Richness by Integrating Local Camera Trap Surveys: RICH et al." *Global Ecology and Biogeography* 26, no. 8: 918–929. https://doi.org/10.1111/geb.12600.

Rich, L. N., D. A. W. Miller, H. S. Robinson, J. W. McNutt, and M. J. Kelly. 2016. "Using Camera Trapping and Hierarchical Occupancy Modelling to Evaluate the Spatial Ecology of an African Mammal Community." *Journal of Applied Ecology* 53, no. 4: 1225–1235. https://doi.org/10.1111/1365-2664.12650.

Riggio, J., H. Kija, E. Masenga, F. Mbwilo, F. Van De Perre, and T. Caro. 2018. "Sensitivity of Africa's Larger Mammals to Humans." *Journal for Nature Conservation* 43: 136–145. https://doi.org/10.1016/j.jnc.2018.04.001.

Roberts, N. J. 2011. "Investigation Into Survey Techniques of Large Mammals: Surveyor Competence and Camera-Trapping vs. Transect-Sampling." *Bioscience Horizons: The International Journal of Student Research* 4, no. 1: 40–49. https://doi.org/10.1093/biohorizons/hzr006.

Rogan, M. S., P. A. Lindsey, C. J. Tambling, et al. 2017. "Illegal Bushmeat Hunters Compete With Predators and Threaten Wild Herbivore Populations in a Global Tourism Hotspot." *Biological Conservation* 210: 233–242. https://doi.org/10.1016/j.biocon.2017.04.020.

Rovero, F., and F. Zimmermann. 2017. "Camera Trapping for Wildlife Research. Francesco Rovero and Fridolin Zimmermann, editors. 2016. Pelagic Publishing, Exeter, UK, 320 pp. $77.78 hardcover. 978-1-784-27063-6: Book Review." *Journal of Wildlife Management* 81, no. 6: 1125. https://doi.org/10.1002/jwmg.21293.

Salerno, J., M. Borgerhoff Mulder, M. N. Grote, M. Ghiselli, and C. Packer. 2016. "Household Livelihoods and Conflict With Wildlife in Community-Based Conservation Areas Across Northern Tanzania." *Oryx* 50, no. 4: 702–712. https://doi.org/10.1017/S0030605315000393.

Severre, E. L. M. 2014. "Ipole Pilot Wildlife Management Area Resource Management Zone Plan (2004–2014)."

Shannon, G., L. S. Cordes, A. R. Hardy, L. M. Angeloni, and K. R. Crooks. 2014. "Behavioral Responses Associated With a Human-Mediated Predator Shelter." *PLoS One* 9, no. 4: e94630. https://doi.org/10.1371/journal.pone.0094630.

Silveira, L., A. T. A. Jácomo, and J. A. F. Diniz-Filho. 2003. "Camera Trap, Line Transect Census and Track Surveys: A Comparative Evaluation." *Biological Conservation* 114, no. 3: 351–355. https://doi.org/10.1016/S0006-3207(03)00063-6.

Smit, J. B. 2023. "Elephants in a Landscape of Risk: Spatial, Temporal, and Behavioural Responses to Anthropogenic Risk in African Savannah Elephants."

Smith, J. A., E. Donadio, J. N. Pauli, M. J. Sheriff, and A. D. Middleton. 2019. "Integrating Temporal Refugia Into Landscapes of Fear: Prey Exploit Predator Downtimes to Forage in Risky Places." *Oecologia* 189, no. 4: 883–890. https://doi.org/10.1007/s00442-019-04381-5.

Soultan, A., O. Attum, and W. Lahue. 2021. "The Relationship between Landscapefeatures and Domestic Species on the Occupancy of Native Mammals in Urbanforests." *Urban Ecosystems* 24, no. 6: 1117–1128. https://doi.org/10.1007/s11252-021-01100-y.

Steinbeiser, C. M., J. Kioko, A. Maresi, R. Kaitilia, and C. Kiffner. 2019. "Relativeabundance and Activity Patterns Explain Method-Related Differences in Mammalianspecies Richness Estimates." *Journal of Mammalogy* 100, no. 1: 192–201. https://doi.org/10.1093/jmammal/gyy175.

Strampelli, P., P. Henschel, C. E. Searle, et al. 2022. "Index-Based Large Carnivore Population Density and Abundance Estimates for the Ruaha-Rungwa Conservation Complex in Tanzania." *African Journal of Ecology* 61: 221–225. https://doi.org/10.1111/aje.13092.

Strinning, T. 2006. "Evaluation de la contribution de la chasse sportive au développement des communautés et à la conservation de la faune."

Titeux, N., O. Aizpurua, F. A. Hollander, et al. 2020. "Ecological Traps and Species Distribution Models: A Challenge for Prioritizing Areas of Conservation Importance." *Ecography* 43, no. 3: 365–375. https://doi.org/10.1111/ecog.04783.

Tucker, M. A., L. Santini, C. Carbone, and T. Mueller. 2020. "Mammal Population Densities at a Global Scale Are Higher in Human-Modified Areas."

Verschueren, S., W. D. Briers-Louw, P. Monterroso, and L. Marker. 2021. "Local-Scale Variation in Land Use Practice Supports a Diverse Carnivore Guild on Namibian Multiple-Use Rangeland." *Rangeland Ecology & Management* 79: 64–76. https://doi.org/10.1016/j.rama.2021.07.007.

Vesey-FitzGerald, D. F. 1960. "Grazing Succession Among East African Game Animals." *Journal of Mammalogy* 41, no. 2: 161. https://doi.org/10.2307/1376351.

Villard, L. 2022. "*Camera trap monitoring of Rungwa North Open Area.pdf.*"

Voeten, M. M., C. A. D. M. van de Vijver, H. Olff, and F. van Langevelde. 2010. "Possible Causes of Decreasing Migratory Ungulate Populations in an East African Savannah After Restrictions in Their Seasonal Movements." *African Journal of Ecology* 48, no. 1: 169–179. https://doi.org/10.1111/j.1365-2028.2009.01098.x.

William Nyahongo, J. 2024. "Dry-Season Motorbike Movement Patterns in Four Villages in Serengeti and Dodoma Districts, Tanzania: Does the Movement Patterns Reflect the Night Usage in Illegal Hunting?" *Transportation Research Interdisciplinary Perspectives* 28: 101246. https://doi.org/10.1016/j.trip.2024.101246.

Williams, K. S., R. T. Pitman, G. K. H. Mann, et al. 2021. "Utilizing Bycatch Camera-Trap Data for Broad-Scale Occupancy and Conservation: A Case Study of the Brown Hyaena *Parahyaena brunnea*." *Oryx* 55, no. 2: 216–226. https://doi.org/10.1017/S0030605319000747.

Zurkinden, D. 2017. "Etude de l'abondance relative et de la structure d'une communauté de carnivores dans un écosystème de forêt sèche sur une base de données de pièges *photographiques*."

Zwerts, J. A., P. J. Stephenson, F. Maisels, et al. 2021. "Methods for Wildlife Monitoring in Tropical Forests: Comparing Human Observations, Camera Traps, and Passive Acoustic Sensors." *Conservation Science and Practice* 3, no. 12: e568. https://doi.org/10.1111/csp2.568.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** aje70145-sup-0001-Supinfo.docx.