Assessing the impact of human disturbance on mammal distributions within a community conservation area in east Africa

Master thesis

Faculty of Science, University of Bern

Handed in by

Lucy Novovitch

2023

Supervised by

Dr. Ian Ausprey

Prof. Dr. Raphaël Arlettaz

Assessing the impact of human disturbance on mammal distributions within a community conservation area in east Africa

Lucy H. Novovitch[1], Luca Villard[2], Claude Fischer[2], Yves Hausser[2], Sandy Mermod[2], Raphaël Arlettaz[1] & Ian Ausprey[1]

[1]Division of Conservation Biology, Institute of Ecology & Evolution, University of Bern, Baltzerstrasse 6, 3012 Bern, Switzerland
[2]Association pour le développement des aires protégées (ADAP), Rue des Savoises 15, 1205 Genève, Switzerland

Abstract

Community conservation areas offer a new approach to land management in East African countries by employing governance strategies that transition decision-making from state- to community-controlled processes emphasizing the rights of local people. Because this conservation model necessarily embraces local livelihoods, research is needed to examine how common forms of human disturbance found within community conservation areas potentially impact local biodiversity. Here, we present results from the first systematic camera trap survey conducted at Ipole Wildlife Management Area (WMA) in the Sikonge District of Tanzania. Ipole WMA is a community conservation area dedicated to wildlife conservation and promotion of commodities that support local livelihoods, including beekeeping, timbering, fishing, and cattle grazing. Such practices have produced a range of human-induced disturbances within the WMA, including the development of roads and small trails, as well as increased human presence near commodity production sites. Between July and November 2022, we placed camera traps throughout the Ipole WMA to quantify the diversity of the mammal community and examine how mixed-intensity forms of anthropogenic disturbance, such as villages, roads, trails, and cattle grazing, correlate with mammal occupancy. We also assessed how the Koga River (the primary water source within the WMA) and vegetation structure (grasslands vs. open woodlands) influence mammal occupancy during the dry season.

In total, we detected 52 wild mammal species ranging from relatively small species (e.g., East African Springhare (Pedetes surdaster)) to large megafauna (e.g., African elephant (Loxodonta africana)). Using multi-species spatial occupancy models for 38 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. Specifically, 10 species (26%) were found closer to roads or trails (e.g., Sylvicapra grimmia, Phacochoerus africanus, Ichneumia albicauda), 11 species (29%) appeared to avoid villages (e.g., Syncerus caffer, Hippotragus niger, Damaliscus l. jimela), and 17 species (45%) were found closer to the river (e.g., Tragelaphus strepsiceros, Leptailurus serval, Civettictis civetta). Additionally, 15 species (39%) appeared to avoid disturbance associated with commodity production, such as cattle grazing (e.g., Potamochoerus larvatus, Hystrix africaeaustralis, Genetta angolensis). Vegetation structure was strongly correlated with only two species: the Topi (Damaliscus l. jimela) which specifically selects open grassland habitats and the yellow baboon (Papio cynocephalus) which prefers open woodlands. Our results demonstrate that common forms of human disturbance found within community conservation areas can potentially impact mammal distributions. We provide species lists and predicted occupancy maps of all modeled species to be used as decision-support tools by rangers and other decision-makers within the Ipole WMA.*

421 words

Keywords

Community-managed conservation areas, Camera trapping, Species richness, Occupancy, Detection, Anthropogenic activities, environmental variables

1.Introduction

Community-managed conservation areas are an important approach to conserving biodiversity within Africa (Lee, 2018). In East African countries, specifically Tanzania, community-based natural resource management (CBNRM) of wildlife occurs through the creation of Wildlife Management Areas (WMA)(Lee & Bond, 2018). Currently, nineteen WMAs are operating in Tanzania, encompassing 7% of the country's land area (Lee & Bond, 2018). WMAs often contain multiple villages that dedicate lands to wildlife conservation, and share associated tourism-revenues (Lee & Bond, 2018). This strategy marks a transition from state-controlled to community-controlled wildlife management, and can be viewed as an alternative to "top down" conservation approaches like national parks or protected areas that exclude local people from land management (Kiwango et al., 2018).

The governance of Wildlife Management Areas involves multiple expectations: (1) it seeks localized expertise of biodiversity as facilitated through local institutions and traditional practices (Phuthego & Chanda, 2004), (2) it hopes to empower local communities regarding land and resource management (Bluwstein et al., 2016), and (3) it ultimately aims to increase wildlife densities and protection while minimizing human disturbance (Kiffner et al., 2020; Lee & Bond, 2018). However, community-managed areas can generate tensions among local communities, private investors and government authorities regarding economic interests (Raycraft, 2022). Specific cases in Tanzania demonstrated that WMAs fostered limited ownership, and collective action at the community level due to resource centralization by the WMA governance (Bluwstein et al., 2016). It has been shown in case-studies that when implementing a WMA it is essential to involve local communities throughout the development process to effectively promote the idea of a community-based approach with economic benefits (Kiwango et al., 2018). Concrete actions and land use plans that respect the rights of local people while promoting wildlife are key to making WMAs durable (Raycraft, 2022).

Because community conservation areas necessarily embrace local livelihoods, they must manage for biodiversity in the context of mixed-intensity disturbances commonly associated with commodity production and other economic opportunities, such as tourism hunting, timber production, fishing, honey production, or mushroom harvesting (Bloesch, 2020; Hausser & Mpuya, 2004; Strinning, 2006). When registered as legal activities with proper permits such practices have potential to provide income to local communities (Bloesch, 2020; Hausser & Mpuya, 2004). While these activities occur sporadically at relatively low intensities and don’t directly target wildlife, they can have negative effects on forests and water quality over elongated periods of time (Kayombo et al., 2013; Kideghesho, 2015). For example, such disturbances can directly and indirectly impact mammal distributions and densities (Caro, 1999). Further intensification can cause animals to avoid heavily exploited areas, leading to changes in community composition (Averbeck et al., 2012). Hunting tourism, in particular, can lead to reduced population densities and, by restricting available lands for colonization, may impact future development of touristic activities such as animal photography (Stankowich, 2008). For these reasons, it is essential that local authorities regulate and control the intensity of legal disturbances within WMAs in order to maintain conservation benefits for both people and biodiversity.

Illegal activities, such as unregulated cattle grazing and poaching can cause more persistent forms of disturbance to wildlife (Caro, 1999; Kablan et al., 2019; Soofi et al., 2018; Wright et al., 2000). Herd protection against predators and providing for themselves while inside the WMA can lead herders to poach (Bouché et al., 2012; Dickman, 2008; Kwaslema et al., 2017; Mishra & Madhusudan, 2002). Poaching reduces population density and endangers rare species (Kablan et al., 2019), while altering sex ratios (Mondol et al., 2014), decreasing genetic diversity (Delgado et al., 2021), and impacting the reproduction of plants dependent upon mammalian dispersers (Piel et al., 2015; Wright et al., 2000). Both legalized hunting and poaching increase the stress of target species, which constrains behavioral activities (Donadio & Buskirk, 2006). Cattle can negatively affect water quality when poorly managed (Hubbard et al., 2004; Strauch et al., 2009), as feces of medicated cows both impact soil and river health. Excessive grazing can lead to competition between livestock and wild ungulates, which indirectly impacts both carnivores dependent upon herbivores as prey and small mammals that use vegetation for shelter (Mishra & Madhusudan, 2002; Schieltz & Rubenstein, 2016). As a result, illegal cattle presence may pose potential threats to wildlife through their impact on vegetation structure, water quality, and disease transmission (Hubbard et al., 2004; Morgan et al., 2006; Schieltz & Rubenstein, 2016). Livestock is globally increasing in Tanzania and goes hand in hand with illegal intrusions into protected areas. Documentation of illegal grazing in the country remains rare, and little is known about its drivers (Musika et al., 2021).

In the present study, we investigated the impact of human activities on the distribution of wildlife within the Ipole WMA in central Tanzania. Ipole WMA is an excellent example of a community conservation area yet has not had a comprehensive assessment of its mammal community nor an assessment of how human activities within the WMA impact mammal distributions. Specifically, we had two objectives: (1) Assess mammal diversity and species-specific occupancy within the WMA using camera trapping and transect survey approaches, and (2) Assess the influence of anthropogenic disturbance on mammal occupancy, including proximity to villages, roads, and trails, as well as the extent of low-intensity agricultural practices like cattle grazing and beekeeping. We also assessed how two natural environmental features known to influence mammal behavior correlated with species-specific occupancy: (1) the extent of grassland vs. woodland habitat and (2) proximity to the Koga River, which is the main water source for the region (Montalvo et al. 2019; Cavada et al. 2019).

1.Study area

This study was conducted within the Ipole Wildlife Management Area (WMA) located near the village of Ipole in the Sikonge District of Tabora, Tanzania. The WMA consists mainly of flat grassland savanna with patches of open woodland and wooded grassland and is partially bordered by the Koga River. Seasonal flooding events (November - May) submerge up to 20% of the WMA. The area of the WMA is approximately 2540 km^2.

The WMA is managed by the JUHIWAI (Jumuiya ya Hifadhi ya Wanyamapori Ipole) community conservation association, which provides rangers, logistics, and monitors the use of the WMA. It is composed of representatives from local villages (Ipole, Msuya, Idekamiso, Utimule, Ugunda, and Mwamulu) which together take decisions regarding its management. Continuous patrolling over the territory and in the vicinity are deployed to prevent illegal activities and ensure security of the villages and surrounding natural resources.

Management regulations permit low-intensity multiple-use practices, including limited hunting of 25 common species, fishing, timber extraction, and production of honey (Tanzania Wildlife Management Authority). While these practices are regulated and enforced by JUHIWAI, infractions still occur, including illegal logging within the core area of the reserve, poaching, and improper organization of beehives. Such illegal activity is driven, in part, by the flat local topography and ease of access to villages bordering the reserve. Ipole WMA faces further challenges due to confusion over the administrative status of the reserve. It is managed concurrently as a WMA, a hunting game reserve, and a forest management reserve, which complicates efforts to enact and maintain consistent management procedures.

Ipole WMA is currently receiving assistance from the Swiss-based non-governmental organization Association pour le Développement des Aires Protégées (ADAP), that has worked for over 20 years in the region on projects regarding biodiversity conservation and local livelihoods. ADAP's goals for Ipole WMA include (1) informing local people on ecological methods to produce and harvest commodities (e.g., honey, mushrooms, fisheries, livestock), (2) clarifying the legal status of the reserve and its specific management mandates, (3) training rangers to assist and implement systematic surveys of the local fauna using transect counts and camera trapping, and (4) facilitating decision-making and sustainable activities in the region (https://www.adap.ch/category/activites/projets/). We conducted this study in 2022 with the assistance of ADAP and consent and support of JUHIWAI.

2. Materials and Methods

We sampled six 10 km^2 grids within the Ipole WMA that had previously been delineated by ADAP (Fig. 2). Grids covered 600 km^2. Grids were positioned to sample all major habitats found within the WMA while maintaining logistical access for researchers and rangers. Grids were positioned similar to other monitoring efforts conducted in the region in order to maintain comparability among studies (Fischer et al., 2013; Hausser et al., 2017; Villard, 2022).

We systematically sampled the mammal community within each grid using a combination of camera trap and visual-based transect surveys (Fig. 3, Fig. 4). We used these two survey approaches to increase species detectability and mitigate biases present in both methodologies. Camera traps may result in biases in detection, such as sensitivity issues that underestimate certain species, failures of equipment that reduce detections of rare or elusive species, failure to detect small species lying below the camera field of view, or by producing a surplus of junk images stemming from vegetation movement, clouds, winds, or heat (Amin et al., 2015; Apps & McNutt, 2018). Visual-based transect surveys may result in biases in detection as well. Vegetation cover and flight distances of mammals can underestimate species richness, especially if increased hunting pressure alters animal behavior (Hausser et al., 2017). Differences among observers might also lead to taxonomic biases (Lardner et al., 2019).

Camera trapping is widely used to study mammal distributions and community patterns throughout the world, particularly in Africa (Cavada et al., 2019; Hausser et al., 2017; Williams et al., 2021). Regarding performance in species detectability they have been proven to be the most effective method compared to other approaches such as visual- based transects, opportunistic encounters or car-transects (Hausser et al., 2017). However, visual-based transects have been proven effective for inventory purposes (Hausser et al., 2017). For this project we combined both methodologies because we were already systematically walking 2 km between each camera site during camera trap set up and recovery and combining camera trap and visual-based transect were likely to increase species detectability and reduce false absences (Farris et al., 2014; Moore et al., 2020; Wix & Reich, 2019). Finally, the approaches used during this project were similarly applied to other surveyed sites by ADAP (Delisle, 2014). Thus, it made sense for comparison purposes to follow a similar protocol.

2.1 Camera traps

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). We selected 2 x 2 km^2, because it maximizes detections of species with small and large territories and has been shown to be effective in past studies conducted by ADAP in the region (Buffard, 2018; Fischer et al., 2013; Villard, 2022). Camera spacing also exceeded the average territory size of most of our species, which helped to avoid repeat sampling of individuals at multiple camera sites (Rovero et al. 2013). We sampled grids during the dry season (beginning of May through end of October), with half sampled in July - August and the remainder sampled in September – October. Cameras operated for approximately one month during each survey session. We do not believe the different sampling dates produced biases, because all sampling occurred during the dry season when mammals rely on fixed resources and are generally less nomadic (Birkett et al., 2012; Vesey-FitzGerald, 1960).

Cameras were set to intermediate sensitivity with an interval of 1 minute between each trigger in order 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 within 100 m of animal tracks in order to increase detection probability.

2.2 Transects

We visually searched for animal signs along 2 km transects between each camera site. While walking we systematically reported each opportunistic sighting, categorizing each as either direct (actual sighting of an animal) or indirect (signs of animal presence such as scats and tracks). Transects were completed twice, once during camera setup and once during retrieval. All direct and indirect sightings were conducted by local rangers with extensive experience identifying animal sign in the region. Additionally, we conducted regular "calibration" sessions to ensure consistency in identification among observers. For each sighting we recorded the coordinates, time, observer, species, and if the sighting was direct or indirect. For direct sightings, we also recorded the sex and age if possible and number of individuals. For indirect sightings we recorded, the state (Fresh<1 day or Old>1 day), and habitat (grassland vs. woodland). In total we surveyed 153 transects two times and 34 transects one time due to logistical complications (Fig. 4).

2.3 Analysis

2.3.1 Species Richness

We pooled all data from camera trap and transect surveys to create a list of all mammal species detected within the WMA. We assessed our sampling effort by calculating the sample coverage across all cameras, transects, and visits using the function "iNEXT" (function 'iNEXT()' in package 'iNEXT-package')(Hsieh et al., 2022) (Fig. 5, Fig. 6, Fig. 7).

2.3.1 Occupancy Modelling

We used data from the camera trap surveys to estimate species-specific occupancy across the WMA. We processed photos using Lepus (Huber, 2018. Lepus [Online Software] Version 4.2.), and animals were identified to species when possible. Only photos double-checked and approved by Pf. Dr. Yves Hausser were included in our dataset. Images were then divided into four separate weeks, and each week was treated as a repeat visit (Duarte, 2017). We restricted our analysis of camera trap data to (1) species detected at least three times and (2) cameras operating for at least 5 days. This resulted in a total of 39 species with sufficient observations, including domestic species (*Bos taurus africanus, Canis lupus familiaris, Capra hircus*) that will be named and regrouped as "Anthropic sign" in our dataset, and 183 cameras used for occupancy analyses (Fig. 3).

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 'spMsPGOcc' in package 'SpOccupancy-package') (Doser et al., 2022). Inference was made from 510 samples of posterior distributions obtained from three chains (20'000 iterations) with a burn-in of 3000 and thinned by 100. Convergence was assessed by visual inspection of the chains and ensuring that the Gelman-Rubin statistic was close to 1 for each parameter. In total we ran three models due to correlations between the covariates of interest that prevented us from running all variables together.

Habitat Model. For the occupancy component of this model, we incorporated a covariate for the proportion of grassland vs. woodland habitat found within a 500m radius of each camera trap. We chose to explain species distributions through this habitat rather than open woodland because: (1) Open grassland is the main habitat inside the WMA (Fig. 1), (2) The number of detected species in open grassland were higher than open woodland (Fig. 14, Fig. 15), and (3) The major form of anthropogenic disturbance (livestock) was more common in open grassland habitat. For the detection component of the model, we incorporated as a covariate the log number of days each camera was active, which accounts for variability in camera availability due to premature battery failure and memory card failure.

Occupancy (ψ): $Logit(\psi ij) = \beta oi + \beta 1i \times Cov.OGj$

Detectability (p): $Logit(\mathrm{p}ij) = \alpha oi + \alpha 1i \times daysj$

Anthropogenic Disturbance Model #1. For the occupancy component of this model, we incorporated 4 covariates predicted to potentially influence species distributions: distance of each camera trap from three forms of human disturbance (roads, trails, and villages), as well as distance from the Koga River. For the detection component of the model, we incorporated as a covariate the log number of days each camera was active, as well as the proportion of open grassland in a 500m radius around the camera site, given that vegetation structure could impact detectability.

Occupancy (ψ): $Logit(\psi ij) = \beta oi + \beta 1i \times Drivj + \beta 2i \times Dtrailsj + \beta 3i \times Dvillagesj + \beta 4i \times Droadsj$

Detectability (p): $Logit(\mathrm{p}2ij) = \alpha oi + \alpha 1i \times daysj + \alpha 2i \times Cov.OGj$

Anthropogenic Disturbance Model #2. For the occupancy component of this model, we incorporated one covariate predicted to potentially influence species distributions: distance of each camera trap from anthropogenic activities (e.g., livestock, human, dogs). Human presence could either be linked to cattle, beekeeping, timber production or poaching. We included the same covariates for detectability as above.

Occupancy (ψ): $Logit(\psi ij) = \beta oi + \beta 1i \times Danthj$

Detectability (p): $Logit(\mathrm{p}ij) = \alpha oi + \alpha 1i \times daysj + \alpha 2i \times Cov.OGj$

Predicted occupancy maps.

We calculated distance rasters for each covariate of interest (rivers, roads, tracks, villages) using the raster calculator in QGIS 3.22 and built a stacked raster (function 'stack' in the 'raster-package') 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 (x[1-4], rivers, roads, tracks, villages) with its equivalent MPD (psi.coeff.x). For each species, the result of this function is used to calculate predicted occupancy values at the pixel scale (Villard, 2022):

```
fun.psi<-function(x) { x[1]*psi.coeff.rivers + x[2]*psi.coeff.roads +
x[3]*psi.coeff.trails + x[4]*psi.coeff.villages }
```

The function "fun.psi()" sums the coefficients of each covariate to create a map that reflects the predicted occupancy values, considering each variable's influence. We superimposed the stacked distance rasters with the results of the function "fun.psi()" at the species and community level using the "calc()" function (in the 'raster-package') in Rstudio 2022.02.3. These analyses enabled us to create maps that include the MPDs of all four environmental covariates, reflecting the range inoccupancy of a species over the whole area.

3.Results

3.1 Species richness of mid-sized mammals of Ipole WMA

We detected a total of 52 species when pooling data across the two sampling approaches. Sample coverage (SC) was 99.63% (Fig. 5), meaning that we sufficiently sampled the local mammal community.

3.1.1 Camera traps

Across the 183 cameras, we detected 50 mammal species, including 4 species of small mammals (*Cricetomys gambianus, Thryonomys swinderianus, Galago senegalensis, Petrodromus tetradactylus*) (Table 2), 42 species of mid-sized mammals (e.g., *Crocuta crocuta*, *Alcelaphus b. lichtensteinii*, *Damaliscus l. jimela*, *Sylvicapra grimmia*, *Redunca arundinum*, *Phacochoerus africanus*, *Papio cynocephalus*, etc.), and 3 large species (African elephant (*Loxodonta africana*), Giraffe (*Giraffa c. tippelskirchi*), African buffalo (*Syncerus caffer*)) (Table 1). We also detected one bird species of interest that is rare in the region, the ostrich (*Struthio camelus*). When comparing the species diversity of Ipole WMA to the other sites surveyed by ADAP we detected a new species in the region, the Aardwolf (*Proteles cristata*).

3.1.2 Transects

In total, we detected 36 species, including 32 medium-sized species, 3 big mammals (*Loxodonta africana, Syncerus caffer, Giraffa c. tippelskirchi*), and the ostrich (Table 3). We observed three species that were barely or not detected with the camera traps: indirect signs of wild dogs (*Lycaon pictus*) and indirect and direct sightings of the caracal (*Caracal caracal*) and lion (*Panthera leo*).

3.2 Environmental variables correlating with occupancy of mid-sized mammals

3.2.1 Habitat Associations

We found no correlations between the proportion of open grassland at a camera site and occupancy at a community level (β = -0.036, 90% CI: -0.033 – 0.26). However, we found two strong correlations at the species level for the Topi (*Damaliscus l. jimela)* and the yellow baboon (*Papio cynocephalus*): a positive correlation for the Topi (β = 0.73, 90% CI: -0.022 – 1.46) (Fig. 11) and a negative correlation for the yellow baboon (β = -0.829, 90% CI: -1.86 – 0.0036) (Fig. 11).

3.2.2 Anthropogenic Disturbances

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 (β = 0.20, 90% CI: 0.03 – 0.38) (Fig. 8). At the species level, we found the same pattern for 11 species: *Syncerus caffer*, *Redunca arundinum*, *Phacochoerus africanus*, *Lepus victoriae*, *Hippotragus niger*, *Hippotragus equinus*, *Giraffa c. tippelskirchi*, *Genetta angolensis*, *Equus q. boehmi*, *Damaliscus l. jimela*, *Aepyceros melampus* (Fig. 9). Conversely, we found strong negative correlations for the remaining variables, meaning that community occupancy was higher at sites closer to roads (β = -0.15, 90% CI: -0.31 – -0.008), trails (β = -0.15, 90% CI: -0.30 – 0.008), and the Koga River (β = -0.29, 90% CI: -0.43 – -0.119) (Fig. 8). At the species level, occupancy was higher with proximity to roads for 4 species, to trails for 6 species, and to the river for 17 species. Only one species was positively correlated to distance from roads (*Damaliscus. l. jimela*). In general, signs of humans were found closer to villages (β = -0.56, 90% CI: -0.92 – -0.21) and trails (β = -0.41, 90% CI: -0.75 – -0.05).

When only considering anthropogenic signs as an environmental covariate, occupancy at the community level was positively correlated (β = 0.07, 90% CI: 0.027 – 0.11) (Fig. 12), meaning that species across the community more likely occupy sites far from anthropogenic disturbance.

3.2.4 Detection

Probability of detection was positively correlated with the number of active camera days at the community level (β = 0.42, 90% CI: 0.3 – 0.546) and species level for all but 7 species (*Aepyceros melampus, canis adustus, Crocuta Crocuta, Felis silvestris lybica, Hystrix africaeaustralis, Lepus victoriae, Panthera pardus*) (Fig. 14). Detection was positively correlated to the amount of grassland vs. woodland habitat surrounding each camera site. Detection probability increased with larger amounts of open grassland habitat around a give camera trap at the community level (β = 0.14, 90% CI: 0.021 – 0.25) (Fig. 13) and for 9 species (*Aepyceros melampus*, *Damaliscus l. jimela*, *Equus q. boehmi*, *Genetta angolensis*, *Genetta maculata*, *Leptailurus serval*, *Mungos mungo*, *Ourebia ourebi*, *Syncerus caffer*, *Tragelaphus strepsiceros*) (Fig. 14). The detection for only one species increased with smaller amounts of open grassland, the common duiker (*Sylvicapra grimmia*) (β = -0.21, 90% CI: -0.44 – -0.008). Livestock detection increased as well with the amount of open grassland (β = 0.22, 90% CI: 0.019 – 0.43).

3.3 Species-specific Responses

3.3.1 Camera traps

We used results from the occupancy and species distribution models from section 2.3.1 to categorize the 38 detected species into 5 categories of response to human disturbance and environmental factors. Predictive maps of selected species and at the community level are presented in the Figures section for each category (Figs 16-29).

3.3.1 Species that avoid villages: Species included the African warthog (*Phacochoerus africanus*), the Masai giraffe (*Giraffa c. tippelskirchi*), and the impala (*Aepyceros melampus*), the African buffalo (*Syncerus caffer*), the common reedbuck (*Redunca arundinum*), the roan antelope (*Hippotragus equinus*), the Angolan genet (*Genetta angolensis*), the Grant's zebra (*Equus q. boehmi*), the African hare (*Lepus victoriae*), the sable antelope (*Hippotragus niger*), and the topi (*Damaliscus l. jimela*) (Fig. 16, Fig. 18, Fig. 20, Fig. 23, Fig. 24, Fig. 25).

3.3.2 Species that are attracted to water: Species included the spotted hyena (*Crocuta Crocuta*), the serval (*Leptailurus serval*), the greater Kudu (*Tragelaphus strepsiceros*), the bushpig (*Potamochoerus larvatus*), the East African springhare (*Pedestes surdaster*), the waterbuck *(Kobus ellipsiprymnus*), the Cape porcupine (*Hystrix africaeaustralis*), the Rusty-spotted genet (*Genetta maculata*), the African civet (*Civettictis civetta*), and the vervet monkey (*Chlorocebus pygerythrus*), the African buffalo (*Syncerus caffer*), the common reedbuck (*Redunca arundinum*), the roan antelope (*Hippotragus equinus*), the Angolan genet (*Genetta angolensis*), the Grant's zebra (*Equus q. boehmi*), and the bushy-tailed mongoose (*Bdeogale crassicauda*) (Fig. 17, Fig. 20, Fig. 26).

3.3.3 Species that are attracted to trails or roads: Species included the Lichtenstein's hartebeest (*Alcelaphus b. lichtensteinii*), the white-tailed mongoose (*Ichneumia albicauda*), and the aardvack (*Orycteropus afer*), the yellow baboon (*Papio cynocephalus*), the African hare (*Lepus victoriae*), the common duiker (*Sylvicapra grimmia*), the yellow baboon (*Papio cynocephalus*), the sable antelope (*Hippotragus niger*), and the bushy-tailed mongoose (*Bdeogale crassicauda*) (Fig. 19, Fig. 22, Fig. 23, Fig. 24, Fig. 26).

3.3.4 Species that avoid anthropogenic activities: Species included the greater Kudu (*Tragelaphus strepsiceros*), the common duiker (*Sylvicapra grimmia*), the common reedbuck (*Redunca arundinum*), the bushpig (*Potamochoerus larvatus*), the African warthog (*Phacochoerus africanus*), the yellow baboon (*Papio cynocephalus*), the oribi (*Ourebia ourebi*), the African hare (*Lepus victoriae*), the white-tailed mongoose (*Ichneumia albicauda*), the Cape porcupine (*Hystrix africaeaustralis*), the sable antelope (*Hippotragus niger*), the roan antelope (*Hippotragus equinus*), the Angolan genet (*Genetta angolensis*), and the bushy-tailed mongoose (*Bdeogale crassicauda*) (Fig. 16, Fig. 20, Fig. 21, Fig. 22, Fig. 23, Fig. 24, Fig. 26).

3.3.5 Species that shows no specific correlations: Species included the aardwolf (*Proteles cristata*), the four-toed elephant shrew (*Petrodromus tetradactylus*), the African leopard (*Panthera pardus*), the oribi (*Ourebia ourebi*), the banded mongoose (*Mungos mungo*), the honey badger (*Mellivora capensis*), the African elephant (*Loxodonta africana*), the crested porcupine (*Hystrix cristata*), the African wildcat (*Felis silvestris lybica*), and the Gambian pouched rat (*Cricetomys gambianus*), the side-striped jackal (*Canis adustus*) (Fig. 27).

4. Discussion

Across both sampling methodologies we found that Ipole WMA hosts at least 52 mammal species. This includes 7 species on the IUCN Red List: *Loxodonta africana* and *Lycaon pictus* (IUCN-EN), *Giraffa.c.tippelskirchi*, *Panthera leo*, and *Panthera pardus* (IUCN-VU), *Syncerus caffer* and *Equus quagga boehmi* (IUCN-NT). We found substantial evidence that mammals at Ipole WMA respond to anthropogenic disturbance, with community occupancy declining with proximity to villages, and increasing with proximity to roads and trails. This suggests that multiple use practices commonly found within community conservation areas may impact the distribution of mammals in grassland and woodland ecosystems of Africa.

Ipole WMA as a Community Conservation Area. Community conservation areas encompass 7% of land areas in Tanzania, with the objectives of protecting wildlife while promoting the rights and decision-making power of local people (Lee, 2018; Lee & Bond, 2018). An overall evaluation of WMAs effectiveness showed that their implementation increased wildlife densities, especially ungulates and giraffes (*Giraffa camelopardalis*), and decreased livestock presence inside the community conservation areas (Lee, 2018; Lee & Bond, 2018). Cases studies demonstrate the effectiveness of WMAs given that they maintain similar wildlife diversity and density level as national parks (Kiffner et al., 2020). In addition, they provide an alternative management paradigm that grants decision-making power to local authorities like JUHIWAI in our study site. For example, they provide training and work for locals who wish to get involved with the WMAs and associated commodities (e.g., ranger field training, beekeeping, and mushroom harvesting). For this reason, WMAs show great potential as mechanisms to mitigate conflicts between villagers, livestock and wildlife (Raycraft, 2022).

Regional Context. Ipole WMA lies in the vicinity of other sites studied by ADAP, including: Inyonga (Game Reserves), Mlele (Game Controlled Areas), and Rungwa (Game Reserves), and could act as a corridor for migrant species with large territory ranges, such as the African elephant (*Loxodonta africana*) and the wild dog (*Lycaon pictus*) that are both detected on a yearly basis at other surveyed sites in the region (Bloesch, 2019; Villard, 2022). The Topi (*Damaliscus l. jimela*), however, is well represented in the WMA and rarely detected in other surveyed study sites, meaning that Ipole WMA remains key for its conservation given its population declines and the pressure it faces from poaching (Hariohay et al., 2022; Phukuntsi et al., 2022).

Impacts of Trails and Roads. Trails and main roads appeared to act as attractants at the community level and for the majority of the species (Fig. 9) which supports results from other studies in similar habitats, especially for carnivores (Burton et al., 2015; Kautz et al., 2021; Rich et al., 2016; Zurkinden, 2017). Roads and trails likely facilitate animal movement by providing flat, compacted surfaces that require less energy expenditure (Blake et al., 2017; Dickson et al., 2005). Being attracted to roads and trails within the WMA may elevate mortality risk for some species given that both carnivores and herbivores are actively hunted and hunters are more likely to use established roads and trails. Likewise, prey may be more susceptible to predation if predators are attracted to roads and trails. For example, the African warthog, sable antelope, common duiker, African hare, and cattle are all potential prey to multiple predators detected within Ipole, including lions, leopards, servals, and wild dogs. Carnivores are known to face a tradeoff when using roads given that they both act as prey attractants and increase risk of encountering humans (Benson et al., 2016). Given the flat topography of Ipole with its numerous human incursions, we expected roads and trails to facilitate occupancy of carnivores. Instead, occupancy of carnivorous species largely did not correlate with roads and trails, but instead the presence of water (Fig. 9). This could be an indication of elevated human disturbance that exceeds the benefits of increased prey availability. Carnivores might actively avoid roads and trails where the risk of being killed from hunters or poachers is too high and remain near the Koga River where human disturbances seem to be the lowest (Fig. 9). In this case, trails and roads would actually act as areas of low predation risk and explain why we observed the inverse correlation between occupancy and road and trail proximity so consistently among prey species. This phenomenon of benefitting from human disturbance proximity has already been shown for avian species and mammals (Møller, 2012; Suraci et al., 2021). We did detect one herbivorous species that strongly avoided main roads, the Topi (*Damaliscus l. jimela*) (Fig. 9). The pressure from hunting activities (Strinning, 2006) in the region towards this herbivore could explain why it avoided areas with higher rates of human disturbance.

Influence of Villages. This study suggests that many mammals may 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 (Møller, 2012). In Ipole we might have expected certain species to increase in occupancy closer to human settlements given that 12 species have been documented to damage crops and attack livestock (*Papio cynocephalus, Hystrix cristata, Potamochoerus larvatus, Phacochoerus africanus, Loxodonta Africana, Panthera leo, Tragelaphus strepsiceros, Syncerus caffer, Madoka kirkii, Aepyceros melampus, Chlorocebus pygerythrus, Hippopotamus amphibius*) (Strinning, 2006). However, all species detected during this study seemed to actively avoid villages (Fig. 9). These results could reflect the months this survey was conducted. The harsher environment limits available vegetation for foraging during the dry season thus reducing the amount of suitable patches with high nutritional values and driving animals to permanent water sources (Boyers et al., 2019; Voeten et al., 2010). Likewise, drier conditions facilitate human access and potentially increase human disturbance within the WMA, pushing animals farther from settlements. Additionally, the majority of species that appear to avoid human proximity are known to be hunted for bushmeat and sport (*Syncerus caffer*, *Redunca arundinum, Phacochoerus africanus, Lepus victoriae, Hippotragus niger, Giraffa. c. tippelskirchi, Damaliscus. l. jimela, Aepyceros melampus, Genetta angolensis*) (Strinning, 2006). This includes the sable antelope, the African warthog, and the Masai giraffe for which we found evidence of poaching during fieldwork.

Human activities. Anthropogenic activities at Ipole WMA (e.g., humans, dogs, cattle, donkeys, and goats) were strongly associated with village proximity, trail proximity, and water (Fig. 9, Fig. 28). They were not present near main roads, potentially because people were avoiding conflict with rangers or other patrols surveying the WMA. They occurred significantly more near trails, which presumably facilitate access, and villages, where people travel frequently to buy medicine, food, or to see their families. Cattle were the biggest threat inside the WMA and were present throughout the area, with particular concentrations near the villages. This reflects other regions of Tanzania, where livestock are expanding and increasingly go hand in hand with poaching as shepherds actively hunt to provide for themselves (Mrosso, 2022). Vegetation was not an obstacle to their detection as they were found in open woodlands and open grasslands, with a slight preference for open woodlands (Fig. 11). This makes sense when considering that ranger patrols have a harder time spotting camps and animals in denser vegetation. Shading from trees might also play a role for comfort and preventing animals from overheating. The shepherds' camps were often equipped with pits, dug for access to water (Fig. 31). These water pits can act as attractants for various species, particularly for scavengers and carnivores, which can potentially result in an ecological trap (Titeux et al., 2020).

Beehives were the second most present anthropogenic activity, but their effects seemed to be less impactful given that most disturbance was limited to their setup and sporadic maintenance. That said, regulation of beehives is necessary given that illegal hives can influence the forest's health when trees are cut and carved to construct them (Kayombo, Mpinga, and Natai 2013).

Water Resources. This study suggest that the Koga 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, especially during the dry season (Cavada et al., 2019; Pettorelli et al., 2010; Rich et al., 2016; Verschueren et al., 2021). Carnivorous species, in particular, seemed to be linked to water presence and could be a consequence of the ability of carnivores to travel long distances, especially if prey were more available near rivers or if they were avoiding anthropogenic disturbance (Rich, Davis, et al., 2017; Rich, Miller, et al., 2017; Suraci et al., 2021). On the right side of the WMA, over a 20 km section of the main road (Fig. 1), there are more than 30 waterholes artificially dug up by workers during their construction for water access. When driving in the area we observed numerous species gathered around the artificial pits. This portion of the road seemed to act as a general attractant for wildlife. However, if poaching for bushmeat were to increase in the same location, it could be considered an ecological trap (Titeux et al., 2020). This effect might be stronger during the dry season (between May and November) as water is rarer and species are therefore more reliant on novel water sources (Montalvo et al., 2019).

Habitat. This study suggested that the occupancy of species was generally not correlated with vegetation structure (Fig. 10). This might be because Ipole WMA has only two big categories of habitat: open grasslands and open woodlands, with smooth transitioning patches between both vegetation types. Ipole WMA has a flat topography and almost no fragmentation of the landscape or ecological barriers, meaning that vegetation structure may not present an impediment to dispersal or other movements (Niebuhr et al., 2015). The rather open landscape composed of grasslands and woodlands with no thickets or denser vegetation may as well play a role in facilitating animal movement (de Knegt et al., 2007). Species would not be constrained to one habitat type and could be detected by visual surveys or camera traps while crossing between suitable habitat patches. The only two species that had a significant link to habitat type were the yellow baboon (*Papio cynocephalus*) that was detected more in open woodland habitat and the Topi (*Damaliscus l. jimela*) that was detected more in open grassland habitat (Fig. 11). Both results are not surprising as they are similar to the animals' habitat preferences (Wahungu, 1998; Yoaciel & Orsdol, 1981). The Topi population has decline recently in Africa (Averbeck et al., 2012; Cotterill, 2003) and Ipole WMA provides open grasslands habitats that are preferred by the species (Fig. 1, Fig. 30), making such habitat of particular importance for management.

Detection. The occupancy modelling showed that the more time the cameras were actively taking photos the more a species would be detected. The positive correlation between the number of active camera days and detection rate was significant for all species except 7 (*Aepyceros melampus, Canis adustus, Crocuta Crocuta, Felis silvestris lybica, Hystrix africaeaustralis, Lepus victoriae, Panthera pardus*) (Fig. 14). For some species the unsignificant correlation could be explained by their elusive character that resulted in fewer detections. Additionally, a few were only detected within a restricted area (*Felis sylvestris lybica, and Panthera pardus*) and were apparently absent from other grids. Detection was also strongly correlated with the amount of open grassland around camera sites at the community level, and for 11 species at the species level. Many of these species favor open grassland habitat, including antelopes and carnivores (*Aepyceros melampus*, *Damaliscus l. jimela*, *Equus q. boehmi*, *Leptailurus serval*, *Mungos mungo*, *Ourebia ourebi*, *Syncerus caffer*, *Tragelaphus strepsiceros*). The only two species with surprising results were *Genetta angolensis* and *Genetta maculate* given that they are more commonly associated with open woodland (Angelici & Luiselli, 2005). These results could be interpreted in three ways: (1) patches of both habitat type (open woodlands and open grasslands) transition in a way that facilitate movement for the species, (2) resource requirements could be fulfilled in open grasslands as well, or (3) detection rate was higher in open grassland habitat due to a clearer view in front of the camera trap.

5. Conservation Implications

Ipole WMA is registered as a wildlife management area, a forest management area, and a hunting game reserve, this triple designation creates confusion due to conflicted interests and competing objectives. Officially registering the territory as a WMA will give more decision-making power to JUHIWAI and greatly simplify its management with clearer goals and fewer conflicts of interest. We believe that a

compromise should be agreed with the Sukuma tribes regarding land use to prevent them from invading key areas key to wildlife, including several endangered species.
The primary objective of a community conservation area is to both support wildlife and local livelihoods while mitigating anthropogenic disturbances. They propose compensatory measures such as commodity development (e.g., beekeeping, mushroom harvesting, timbering) or hunting and photo tourism that provide alternatives to farming or rural development (Bloesch, 2020; Hausser & Mpuya, 2004; Kiffner et al., 2020). As villages appeared a consistent repellent for all species in our study, it is essential to limit their expansion at the WMA's borders to prevent a decrease in species diversity and density that will affect the development of alternative economic opportunities in the region. 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. Conservation plans should be put in place to preserve areas where wildlife seem to aggregate the most and try to negotiate land usage with local people.

Based on our results the Koga River proved to be essential for wildlife at Ipole, with occupancy increasing for almost all species near the riverbanks. 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. With climate change reducing the number of rains during wet seasons, water access will be even more challenging, both for people and animals. Right now, JUHIWAI has no conservation plan for the Koga River, despite it being the main water resource for Ipole. Future measures should be taken to limit human waste and pollution that could alter water quality, including excrement from medicated cows. Rangers should be informed more thoroughly of the river's importance in workshops and trained to adopt proper behavior during fieldwork regarding waste management. Youth outreach programs in South Africa exist that spread knowledge of natural environments and participation in conservation efforts (Kato & Okumu, 2008; Makwaeba, 2004), and similar programs could be implemented at Ipole WMA.

A future goal of research on the Tanzanian mammal community by ADAP should be to examine how the species richness changes among study sites and across years. One priority is delineating potential corridors that could link suitable habitat patches, especially for threatened species such as lions (*Panthera leo*), African elephants (*Loxodonta africana*), giraffes (*Giraffa c. tippelskirchi*), leopards (*Panthera pardus*) or wild dogs (*Lycaon pictus*). This thesis will be shared with ADAP in order to compare the monitoring results regarding species richness and occupancy with other surveyed sites of the organization. We will also write a report for JUHIWAI that includes the predictive maps with recommended measures concerning patrol effort across the territory. The predicted occupancy maps (Figs 16-29) will help JUHIWAI take important management decisions that impact areas most used by mammals and help inform where to increase patrols in relation to epicenters of anthropogenic activity (Fig. 28).

6. Acknowledgments

I thank Dr. Ian Ausprey for helping me with the data treatment and editing and for having supported me throughout the entire project. I thank Prof. Dr. Yves Hausser and Prof. Dr. Raphaël Arlettaz for having given me this unique opportunity to pursue a project from the beginning in such a beautiful place as Tanzania. I also thank Steven Young and Kilian Junker for their help with the editing and valuable comments. I thank Luca Villard who helped me a lot to understand and choose a good approach for analysis and statistical aspects. I thank Sandy Mermod and Prof. Dr. Claude Fischer for their support and knowledge while doing my fieldwork. Finally, I thank JUHIWAI and all the many rangers that helped me with this work while in Tanzania, without them this project would never have been possible.

7. References

Amin, D. R., Tallents, L., & Wacher, T. (2015). *Camera Trap Survey Design*. 3.

Angelici, F. M., & Luiselli, L. (2005). Habitat associations and dietary relationships between two genets, Genetta maculata and Genetta cristata. *Revue d'Écologie (La Terre et La Vie)*, *60*(4), 341–354. https://doi.org/10.3406/revec.2005.1281

Apps, P. J., & McNutt, J. W. (2018). How camera traps work and how to work them. *African Journal of Ecology*, *56*(4), 702–709. https://doi.org/10.1111/aje.12563

Averbeck, C., Plath, M., Wronski, T., & Apio, A. (2012). Effect of human nuisance on the social organisation of large mammals: Group sizes and compositions of seven ungulate species in Lake Mburo National Park and the adjacent Ankole Ranching Scheme. *Wildlife Biology*, *18*(2), 180–193. https://doi.org/10.2981/11-025

Benson, J. F., Sikich, J. A., & Riley, S. P. D. (2016). Individual and Population Level Resource Selection Patterns of Mountain Lions Preying on Mule Deer along an Urban-Wildland Gradient. *PLOS ONE*, *11*(7), e0158006. https://doi.org/10.1371/journal.pone.0158006

Birkett, P. J., Vanak, A. T., Muggeo, V. M. R., Ferreira, S. M., & Slotow, R. (2012). Animal Perception of Seasonal Thresholds: Changes in Elephant Movement in Relation to Rainfall Patterns. *PLoS ONE*, *7*(6), e38363. https://doi.org/10.1371/journal.pone.0038363

Blake, J. G., Mosquera, D., Loiselle, B. A., Romo, D., & Swing, K. (2017). Effects of human traffic on use of trails by mammals in lowland forest of eastern Ecuador. *Neotropical Biodiversity*, *3*(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., Moyo, F., & Kicheleri, R. (2016). Austere conservation: Understanding conflicts over resource governance in tanzanian wildlife management areas. *Conservation and Society*, *14*(3), 218. https://doi.org/10.4103/0972-4923.191156

Bouché, P., Nzapa Mbeti Mange, R., Tankalet, F., Zowoya, F., Lejeune, P., & Vermeulen, C. (2012). Game over! Wildlife collapse in northern Central African Republic. *Environmental Monitoring and Assessment*, *184*(11), 7001–7011. https://doi.org/10.1007/s10661-011-2475-y

Boyers, M., Parrini, F., Owen-Smith, N., Erasmus, B. F. N., & Hetem, R. S. (2019). How free-ranging ungulates with differing water dependencies cope with seasonal variation in temperature and aridity. *Conservation Physiology*, *7*(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., Neilson, E., Moreira, D., Ladle, A., Steenweg, R., Fisher, J. T., Bayne, E., & Boutin, S. (2015). REVIEW: Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. *Journal of Applied Ecology*, *52*(3), 675–685. https://doi.org/10.1111/1365-2664.12432

Caro, T. M. (1999). Densities of mammals in partially protected areas: The Katavi ecosystem of western Tanzania. *Journal of Applied Ecology*, *36*(2), 205–217. https://doi.org/10.1046/j.1365-2664.1999.00392.x

Cavada, N., Worsøe Havmøller, R., Scharff, N., & Rovero, F. (2019). A landscape-scale assessment of tropical mammals reveals the effects of habitat and anthropogenic disturbance on community occupancy. *PLOS ONE*, *14*(4), e0215682. https://doi.org/10.1371/journal.pone.0215682

Cotterill, F. P. D. (2003). *A biogeographic review of tsessebe antelopes Damaliscus lunatus (Bovidae: Alcelaphini) in south-central Africa*.

de Knegt, H. J., Hengeveld, G. M., van Langevelde, F., de Boer, W. F., & Kirkman, K. P. (2007). Patch density determines movement patterns and foraging efficiency of large herbivores. *Behavioral Ecology*, *18*(6), 1065–1072. https://doi.org/10.1093/beheco/arm080

Delgado, P. M., Argüelles, C. F., & DeMatteo, K. E. (2021). Using noninvasive techniques to monitor game species targeted by poaching in Misiones, Argentina. *Neotropical Biodiversity*, *7*(1), 78–85. https://doi.org/10.1080/23766808.2021.1897354

Delisle, L. (2014). *EVALUATION COMPARATIVE DE LA VALEUR DE CONSERVATION DE DIFFERENTES AIRES PROTEGEES TANZANIENNES PAR LE BIAIS DE PIEGES PHOTOGRAPHIQUES*.

Dickman, A. J. (2008). *KEY DETERMINANTS OF CONFLICT BETWEEN PEOPLE AND WILDLIFE, PARTICULARLY LARGE CARNIVORES, AROUND RUAHA NATIONAL PARK, TANZANIA*.

Dickson, B. G., Jenness, J. S., & Beier, P. (2005). INFLUENCE OF VEGETATION, TOPOGRAPHY, AND ROADS ON COUGAR MOVEMENT IN SOUTHERN CALIFORNIA. *Journal of Wildlife Management*, *69*(1), 264–276. https://doi.org/10.2193/0022-541X(2005)069<0264:IOVTAR>2.0.CO;2

Donadio, E., & Buskirk, S. W. (2006). Flight behavior in guanacos and vicuñas in areas with and without poaching in western Argentina. *Biological Conservation*, *127*(2), 139–145. https://doi.org/10.1016/j.biocon.2005.08.004

Doser, J. W., Finley, A. O., Kéry, M., & Zipkin, E. F. (2022). spOccupancy: An R package for single-species, multi-species, and integrated spatial occupancy models. *Methods Ecol Evol.*, *13*, 1670–1678.

Duarte, A. (2017). Camera Trapping for Wildlife Research. FrancescoRovero and FridolinZimmermann, editors. 2016. Pelagic Publishing, Exeter, UK. 320 pp. $77.78 hardcover. ISBN: 978-1-784-27063-6.: Book Review. *The Journal of Wildlife Management*, *81*(6), 1125–1125. https://doi.org/10.1002/jwmg.21293

Farris, Z. J., Karpanty, S. M., Ratelolahy, F., & Kelly, M. J. (2014). Predator–Primate Distribution, Activity, and Co-occurrence in Relation to Habitat and Human Activity Across Fragmented and Contiguous Forests in Northeastern Madagascar. *International Journal of Primatology*, *35*(5), 859–880. https://doi.org/10.1007/s10764-014-9786-0

Fischer, C., Tagand, R., & Hausser, Y. (2013). *Diversity and distribution of small carnivores in a miombo woodland within the Katavi region, Western Tanzania*. *48*, 7.

Hariohay, K. M., Nassary, D. S., Lyamuya, R. D., & Røskaf, E. (2022). *Local people's knowledge of topi (Damaliscus lunatus) and their illegal hunting for bushmeat consumption in the Serengeti Ecosystem*.

Hausser, Y., & Mpuya, P. (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., Tagand, R., Vimercati, E., Mermod, S., & Fischer, C. (2017). Comparing survey methods to assess the conservation value of a community-managed protected area in western Tanzania. *African Journal of Ecology*, *55*(1), 1–11. https://doi.org/10.1111/aje.12301

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

Hubbard, R. K., Newton, G. L., & Hill, G. M. (2004, January). Water quality and the grazing animal. *Journal of Animal Science*, E255–E263.

Kablan, Y. A., Diarrassouba, A., Mundry, R., Campbell, G., Normand, E., Kühl, H. S., Koné, I., & Boesch, C. (2019). Effects of anti-poaching patrols on the distribution of large mammals in Taï National Park, Côte d'Ivoire. *Oryx*, *53*(3), 469–478. https://doi.org/10.1017/S0030605317001272

Kato, S. S., & Okumu, J. O. (2008). *"Making Bush Meat Poachers Willingly Surrender Using Integrated Poachers Awareness Programme: A Case of Murchison Falls National Park, Uganda"*.

Kautz, T. M., Fowler, N. L., Petroelje, T. R., Beyer, D. E., Svoboda, N. J., & Belant, J. L. (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

Kayombo, C. J., Mpinga, I., & Natai, H. (2013). *Melliferous Status and Activities Endangering Tree Species Composition and Diversity Survey of Mlele Bee Keeping Zone [Mbkz], in Mlele District, Katavi Region-Tanzania.*

Kideghesho, J. R. (2015). Realities on Deforestation in Tanzania—Trends, Drivers, Implications and the Way Forward. In M. Zlatic (Ed.), *Precious Forests—Precious Earth*. InTech. https://doi.org/10.5772/61002

Kiffner, C., Thomas, S., Speaker, T., O'Connor, V., Schwarz, P., Kioko, J., & Kissui, B. (2020). Community-based wildlife management area supports similar mammal species richness and densities compared to a national park. *Ecology and Evolution*, *10*(1), 480–492. https://doi.org/10.1002/ece3.5916

Kiwango, W. A., Komakech, H. C., Tarimo, T. M. C., & Martz, L. (2018). Levels of community participation and satisfaction with decentralized wildlife management in Idodi-Pawaga Wildlife Management Area, Tanzania. *International Journal of Sustainable Development & World Ecology*, *25*(3), 238–248. https://doi.org/10.1080/13504509.2017.1378750

Kwaslema, M. H., Robert, D. F., Jafari, R. K., & Eivin, R. (2017). Assessing crop and livestock losses along the Rungwa-Katavi Wildlife Corridor, South-Western Tanzania. *International Journal of Biodiversity and Conservation*, *9*(8), 273–283. https://doi.org/10.5897/IJBC2017.1116

Lardner, B., Yackel Adams, A. A., Knox, A. J., Savidge, J. A., & Reed, R. N. (2019). Do observer fatigue and taxon bias compromise visual encounter surveys for small vertebrates? *Wildlife Research*, *46*(2), 127. https://doi.org/10.1071/WR18016

Lee, D. E. (2018). Evaluating conservation effectiveness in a Tanzanian community wildlife management area: WMA Effectiveness. *The Journal of Wildlife Management*, *82*(8), 1767–1774. https://doi.org/10.1002/jwmg.21549

Lee, D. E., & Bond, M. L. (2018). Quantifying the ecological success of a community-based wildlife conservation area in Tanzania. *Journal of Mammalogy*, *99*(2), 459–464. https://doi.org/10.1093/jmammal/gyy014

Makwaeba, I. M. (2004). *The use of traditional knowledge in the South African National Parks Imbewu Youth Programme: Planting a seed of environmental awareness*.

Mishra, C., & Madhusudan, M. D. (2002). *AN INCENTIVE SCHEME FOR WILDLIFE CONSERVATION IN THE INDIAN TRANS-HIMALAYA*. 131.

Møller, A. P. (2012). Urban areas as refuges from predators and flight distance of prey. *Behavioral Ecology*, *23*(5), 1030–1035. https://doi.org/10.1093/beheco/ars067

Mondol, S., Mailand, C. R., & Wasser, S. K. (2014). Male biased sex ratio of poached elephants is negatively related to poaching intensity over time. *Conservation Genetics*, *15*(5), 1259–1263. https://doi.org/10.1007/s10592-014-0603-2

Montalvo, V. H., Sáenz-Bolaños, C., Alfaro, L. D., Cruz, J. C., Guimarães-Rodrigues, F. H., Carrillo, E., Sutherland, C., & Fuller, T. K. (2019). Seasonal use of waterholes and pathways by macrofauna in the dry forest of Costa Rica. *Journal of Tropical Ecology*, *35*(2), 68–73. https://doi.org/10.1017/S0266467418000457

Moore, J. F., Pine, W. E., Mulindahabi, F., Niyigaba, P., Gatorano, G., Masozera, M. K., & Beaudrot, L. (2020). Comparison of species richness and detection between line transects, ground camera traps, and arboreal camera traps. *Animal Conservation*, *23*(5), 561–572. https://doi.org/10.1111/acv.12569

Morgan, E. R., Lundervold, M., Medley, G. F., Shaikenov, B. S., Torgerson, P. R., & Milner-Gulland, E. J. (2006). Assessing risks of disease transmission between wildlife and livestock: The Saiga antelope as a case study. *Biological Conservation*, *131*(2), 244–254. https://doi.org/10.1016/j.biocon.2006.04.012

Mrosso, H. T. (2022). *ASSESSMENT OF TRADE FLOWS OF WILDLIFE PRODUCTS: THE CASE OF RUAHA LANDSCAPE, TANZANIA*.

Musika, N. V., Wakibara, J. V., Ndakidemi, P. A., & Treydte, A. C. (2021). Spatio-Temporal Patterns of Increasing Illegal Livestock Grazing over Three Decades at Moyowosi Kigosi Game Reserve, Tanzania. *Land*, *10*(12), 1325. https://doi.org/10.3390/land10121325

Niebuhr, B. B. S., Wosniack, M. E., Santos, M. C., Raposo, E. P., Viswanathan, G. M., da Luz, M. G. E., & Pie, M. R. (2015). Survival in patchy landscapes: The interplay between dispersal, habitat loss and fragmentation. *Scientific Reports*, *5*(1), 11898. https://doi.org/10.1038/srep11898

Pettorelli, N., Lobora, A. L., Msuha, M. J., Foley, C., & Durant, S. M. (2010). Carnivore biodiversity in Tanzania: Revealing the distribution patterns of secretive mammals using camera traps. *Animal Conservation*, *13*(2), 131–139. https://doi.org/10.1111/j.1469-1795.2009.00309.x

Phukuntsi, M. A., Dalton, D. L., Mwale, M., Selier, J., Cebekhulu, T., & Sethusa, M. T. (2022). Genetic patterns in three South African specialist antelope species: Threats, conservation management and their implications. *Conservation Science and Practice*, *4*(12). https://doi.org/10.1111/csp2.12767

Phuthego, T. C., & Chanda, R. (2004). Traditional ecological knowledge and community-based natural resource management: Lessons from a Botswana wildlife management area. *Applied Geography*, *24*(1), 57–76. https://doi.org/10.1016/j.apgeog.2003.10.001

Piel, A. K., Lenoel, A., Johnson, C., & Stewart, F. A. (2015). Deterring poaching in western Tanzania: The presence of wildlife researchers. *Global Ecology and Conservation*, *3*, 188–199. https://doi.org/10.1016/j.gecco.2014.11.014

Raycraft, J. (2022). Community Attitudes Towards Randilen Wildlife Management Area. In C. Kiffner, M. L. Bond, & D. E. Lee (Eds.), *Tarangire: Human-Wildlife Coexistence in a Fragmented Ecosystem* (Vol. 243, pp. 109–125). Springer International Publishing. https://doi.org/10.1007/978-3-030-93604-4_6

Rich, L. N., Davis, C. L., Farris, Z. J., Miller, D. A. W., Tucker, J. M., Hamel, S., Farhadinia, M. S., Steenweg, R., Di Bitetti, M. S., Thapa, K., Kane, M. D., Sunarto, S., Robinson, N. P., Paviolo, A., Cruz, P., Martins, Q., Gholikhani, N., Taktehrani, A., Whittington, J., … Kelly, M. J. (2017). Assessing global patterns in mammalian carnivore occupancy and richness by integrating local camera trap surveys: RICH et al. *Global Ecology and Biogeography*, *26*(8), 918–929. https://doi.org/10.1111/geb.12600

Rich, L. N., Miller, D. A. W., Robinson, H. S., McNutt, J. W., & Kelly, M. J. (2016). Using camera trapping and hierarchical occupancy modelling to evaluate the spatial ecology of an African mammal community. *Journal of Applied Ecology*, *53*(4), 1225–1235. https://doi.org/10.1111/1365-2664.12650

Rich, L. N., Miller, D. A. W., Robinson, H. S., McNutt, J. W., & Kelly, M. J. (2017). Carnivore distributions in Botswana are shaped by resource availability and intraguild species. *Journal of Zoology*, *303*(2), 90–98. https://doi.org/10.1111/jzo.12470

Schieltz, J. M., & Rubenstein, D. I. (2016). Evidence based review: Positive versus negative effects of livestock grazing on wildlife. What do we really know? *Environmental Research Letters*, *11*(11), 113003. https://doi.org/10.1088/1748-9326/11/11/113003

Soofi, M., Ghoddousi, A., Zeppenfeld, T., Shokri, S., Soufi, M., Jafari, A., Ahmadpour, M., Qashqaei, A. T., Egli, L., Ghadirian, T., Chahartaghi, N. R., Zehzad, B., Kiabi, B. H., Khorozyan, I., Balkenhol, N., & Waltert, M. (2018). Livestock grazing in protected areas and its effects on large mammals in the Hyrcanian forest, Iran. *Biological Conservation*, *217*, 377–382. https://doi.org/10.1016/j.biocon.2017.11.020

Stankowich, T. (2008). Ungulate flight responses to human disturbance: A review and meta-analysis. *Biological Conservation*, *141*(9), 2159–2173. https://doi.org/10.1016/j.biocon.2008.06.026

Strauch, A. M., Kapust, A. R., & Jost, C. C. (2009). Impact of livestock management on water quality and streambank structure in a semi-arid, African ecosystem. *Journal of Arid Environments*, *73*(9), 795–803. https://doi.org/10.1016/j.jaridenv.2009.03.012

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

Suraci, J. P., Gaynor, K. M., Allen, M. L., Alexander, P., Brashares, J. S., Cendejas-Zarelli, S., Crooks, K., Elbroch, L. M., Forrester, T., Green, A. M., Haight, J., Harris, N. C., Hebblewhite, M., Isbell, F., Johnston, B., Kays, R., Lendrum, P. E., Lewis, J. S., McInturff, A., … Wilmers, C. C. (2021). Disturbance type and species life history predict mammal responses to humans. *Global Change Biology*, *27*(16), 3718–3731. https://doi.org/10.1111/gcb.15650

Titeux, N., Aizpurua, O., Hollander, F. A., Sardà-Palomera, F., Hermoso, V., Paquet, J., Mestdagh, X., Settele, J., Brotons, L., & Van Dyck, H. (2020). Ecological traps and species distribution models: A challenge for prioritizing areas of conservation importance. *Ecography*, *43*(3), 365–375. https://doi.org/10.1111/ecog.04783

Verschueren, S., Briers-Louw, W. D., Monterroso, P., & Marker, L. (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*(2), 161. https://doi.org/10.2307/1376351

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

Voeten, M. M., van de Vijver, C. A. D. M., Olff, H., & van Langevelde, F. (2010). Possible causes of decreasing migratory ungulate populations in an East African savannah after restrictions in their seasonal movements. *African Journal of Ecology*, *48*(1), 169–179. https://doi.org/10.1111/j.1365-2028.2009.01098.x

Wahungu, G. (1998). Diet and habitat overlap in two sympatric primate species, the Tana crested mangabey *Cercocebus galeritus and yellow baboon Papio cynocephalus* : Diet and habitat overlap in two primates. *African Journal of Ecology*, *36*(2), 159–173. https://doi.org/10.1046/j.1365-2028.1998.00120.x

Williams, K. S., Pitman, R. T., Mann, G. K. H., Whittington-Jones, G., Comley, J., Williams, S. T., Hill, R. A., Balme, G. A., & Parker, D. M. (2021). Utilizing bycatch camera-trap data for broad-scale occupancy and conservation: A case study of the brown hyaena *Parahyaena brunnea*. *Oryx*, *55*(2), 216–226. https://doi.org/10.1017/S0030605319000747

Wix, N., & Reich, M. (2019). Time-triggered camera traps versus line transects – advantages and limitations of multi-method studies for bird surveys. *Bird Study*, *66*(2), 207–223. https://doi.org/10.1080/00063657.2019.1654975

Wright, S. J., Zeballos, H., Domínguez, I., Gallardo, M. M., Moreno, M. C., & Ibáñez, R. (2000). Poachers Alter Mammal Abundance, Seed Dispersal, and Seed Predation in a Neotropical Forest. *Conservation Biology*, *14*(1), 227–239. https://doi.org/10.1046/j.1523-1739.2000.98333.x

Yoaciel, S. M., & Orsdol, K. G. V. (1981). The influence of environmental changes on an isolated topi(Damaliscus Zunatus jimela Matschie)population in the Ishasha Sector of Rwenzori National Park, Uganda. *African Journal of Ecology*, *19*(1–2), 167–174. https://doi.org/10.1111/j.1365-2028.1981.tb00660.x

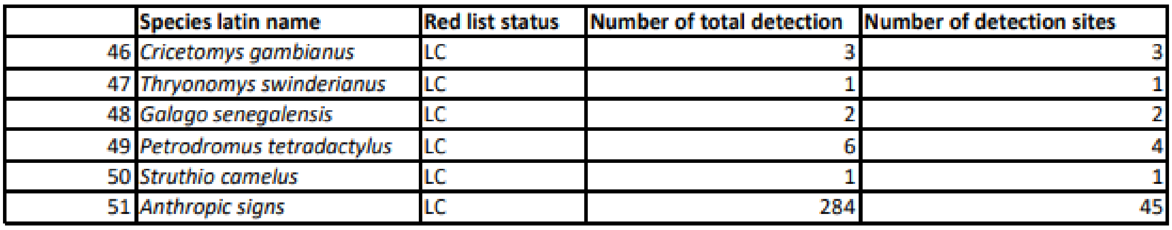
Zurkinden, D. (2017). *Etude de l'abondance relative et de la structure d'une communauté de carnivores dans un écosystème de forêt sèche sur une base de données de pièges photographiques*.

8. Tables and Figures

Table 1: Latin names of detected mammals using camera traps with 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 more threatened).

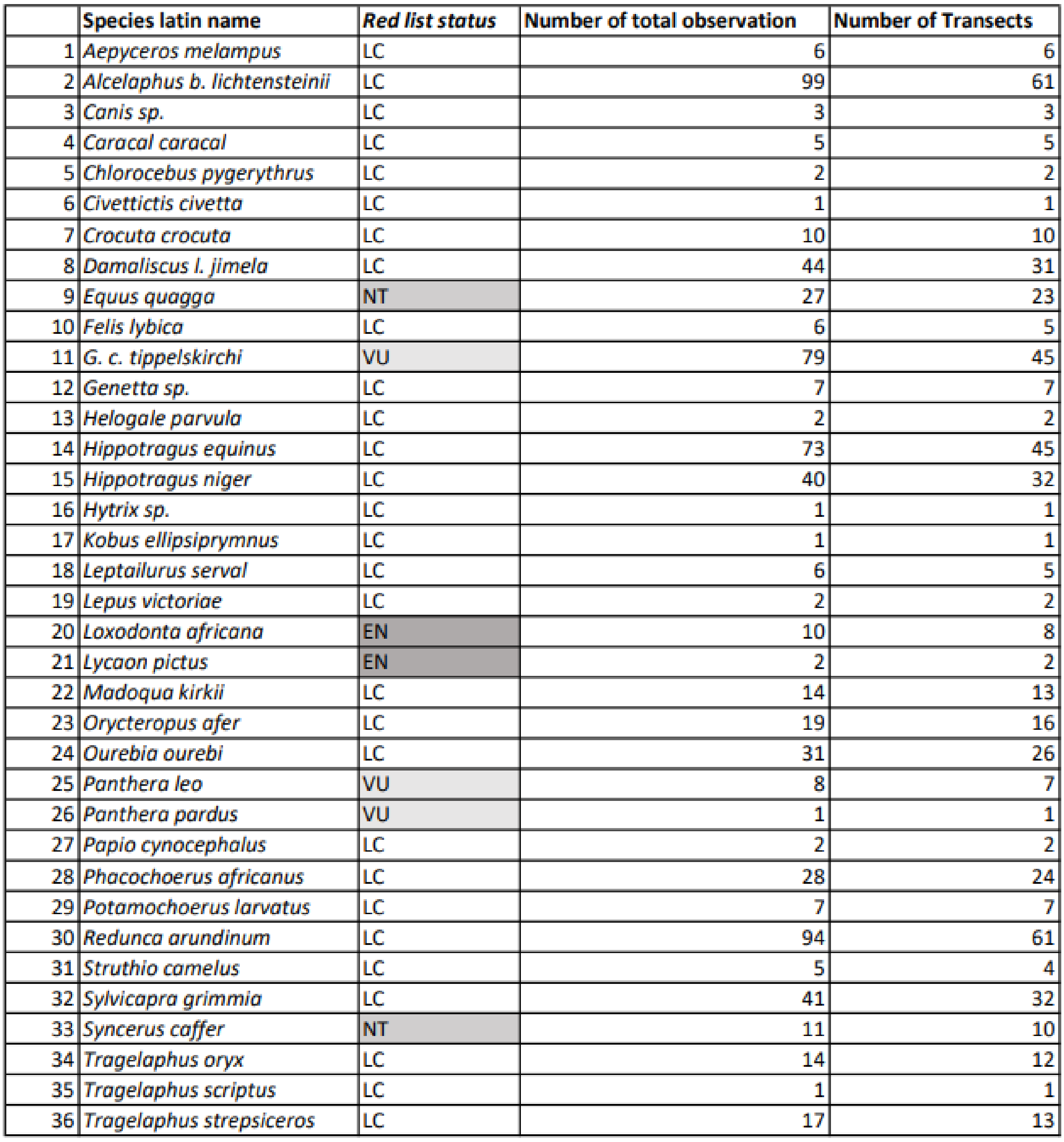
	Species latin name	Red list status	Number of total detection	Number of detection sites
1	*Aepyceros melampus*	LC	8	7
2	*Alcelaphus b. lichtensteinii*	LC	23	18
3	*Bdeogale crassicauda*	LC	8	6
4	*Canis adustus*	LC	12	8
5	*Canis mesomelas*	LC	2	2
6	*Chlorocebus pygerythrus*	LC	41	29
7	*Civettictis civetta*	LC	32	21
8	*Crocuta crocuta*	LC	15	13
9	*Damaliscus l. jimela*	LC	90	39
10	*Equus quagga*	NT	22	14
11	*Felis silvestris lybica*	LC	5	5
12	*Genetta angolensis*	LC	107	63
13	*Genetta maculata*	LC	19	12
14	*Giraffa c. tippelskirchi*	VU	35	16
15	*Helogale parvula*	LC	3	2
16	*Herpestes ichneumon*	LC	2	1
17	*Herpestes sanguineus*	LC	1	1
18	*Hippotragus equinus*	LC	27	21
19	*Hippotragus niger*	LC	50	30
20	*Hystrix africaeaustralis*	LC	17	11
21	*Hystrix cristata*	LC	4	4
22	*Ichneumia albicauda*	LC	18	14
23	*Kobus ellipsiprymnus*	LC	8	3
24	*Leptailurus serval*	LC	21	14
25	*Lepus victoriae*	LC	30	16
26	*Loxodonta africana*	EN	4	4
27	*Madoqua kirkii*	LC	1	1
28	*Mellivora capensis*	LC	33	30
29	*Mungos mungo*	LC	36	25
30	*Orycteropus afer*	LC	11	10
31	*Ourebia ourebi*	LC	48	28
32	*Panthera leo*	VU	1	1
33	*Panthera pardus*	VU	4	4
34	*Papio cynocephalus*	LC	29	19
35	*Pedetes surdaster*	LC	9	4
36	*Phacochoerus africanus*	LC	71	46
37	*Potamochoerus larvatus*	LC	27	22
38	*Proteles cristata*	LC	3	3
39	*Raphicerus sharpei*	LC	2	2
40	*Redunca arundinum*	LC	61	26
41	*Rhynchogale melleri*	LC	1	1
42	*Sylvicapra grimmia*	LC	169	76
43	*Syncerus caffer*	NT	17	9
44	*Tragelaphus scriptus*	LC	2	1
45	*Tragelaphus strepsiceros*	LC	15	12

Table 2: Latin names of detected small-sized mammals using camera traps, as well as one bird species of interest (*Struthio camelus*) and the anthropogenic activities. The number of total detections across sites, the total number of sites where the species was detected, and its red list status is indicated.



	Species latin name	**Red list status**	**Number of total detection**	**Number of detection sites**
46	*Cricetomys gambianus*	LC	3	3
47	*Thryonomys swinderianus*	LC	1	1
48	*Galago senegalensis*	LC	2	2
49	*Petrodromus tetradactylus*	LC	6	4
50	*Struthio camelus*	LC	1	1
51	*Anthropic signs*	LC	284	45

Table 3: Latin names of detected mammals using visual-based transects, size ranging from the African Hare (*Lepus victoriae*) to the African elephant (*Loxodonta africana*) including a bird species of interest (*Struthio camelus*) with 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 more threatened).



	Species latin name	***Red list status***	**Number of total observation**	**Number of Transects**
1	*Aepyceros melampus*	LC	6	6
2	*Alcelaphus b. lichtensteinii*	LC	99	61
3	*Canis sp.*	LC	3	3
4	*Caracal caracal*	LC	5	5
5	*Chlorocebus pygerythrus*	LC	2	2
6	*Civettictis civetta*	LC	1	1
7	*Crocuta crocuta*	LC	10	10
8	*Damaliscus l. jimela*	LC	44	31
9	*Equus quagga*	NT	27	23
10	*Felis lybica*	LC	6	5
11	*G. c. tippelskirchi*	VU	79	45
12	*Genetta sp.*	LC	7	7
13	*Helogale parvula*	LC	2	2
14	*Hippotragus equinus*	LC	73	45
15	*Hippotragus niger*	LC	40	32
16	*Hytrix sp.*	LC	1	1
17	*Kobus ellipsiprymnus*	LC	1	1
18	*Leptailurus serval*	LC	6	5
19	*Lepus victoriae*	LC	2	2
20	*Loxodonta africana*	EN	10	8
21	*Lycaon pictus*	EN	2	2
22	*Madoqua kirkii*	LC	14	13
23	*Orycteropus afer*	LC	19	16
24	*Ourebia ourebi*	LC	31	26
25	*Panthera leo*	VU	8	7
26	*Panthera pardus*	VU	1	1
27	*Papio cynocephalus*	LC	2	2
28	*Phacochoerus africanus*	LC	28	24
29	*Potamochoerus larvatus*	LC	7	7
30	*Redunca arundinum*	LC	94	61
31	*Struthio camelus*	LC	5	4
32	*Sylvicapra grimmia*	LC	41	32
33	*Syncerus caffer*	NT	11	10
34	*Tragelaphus oryx*	LC	14	12
35	*Tragelaphus scriptus*	LC	1	1
36	*Tragelaphus strepsiceros*	LC	17	13

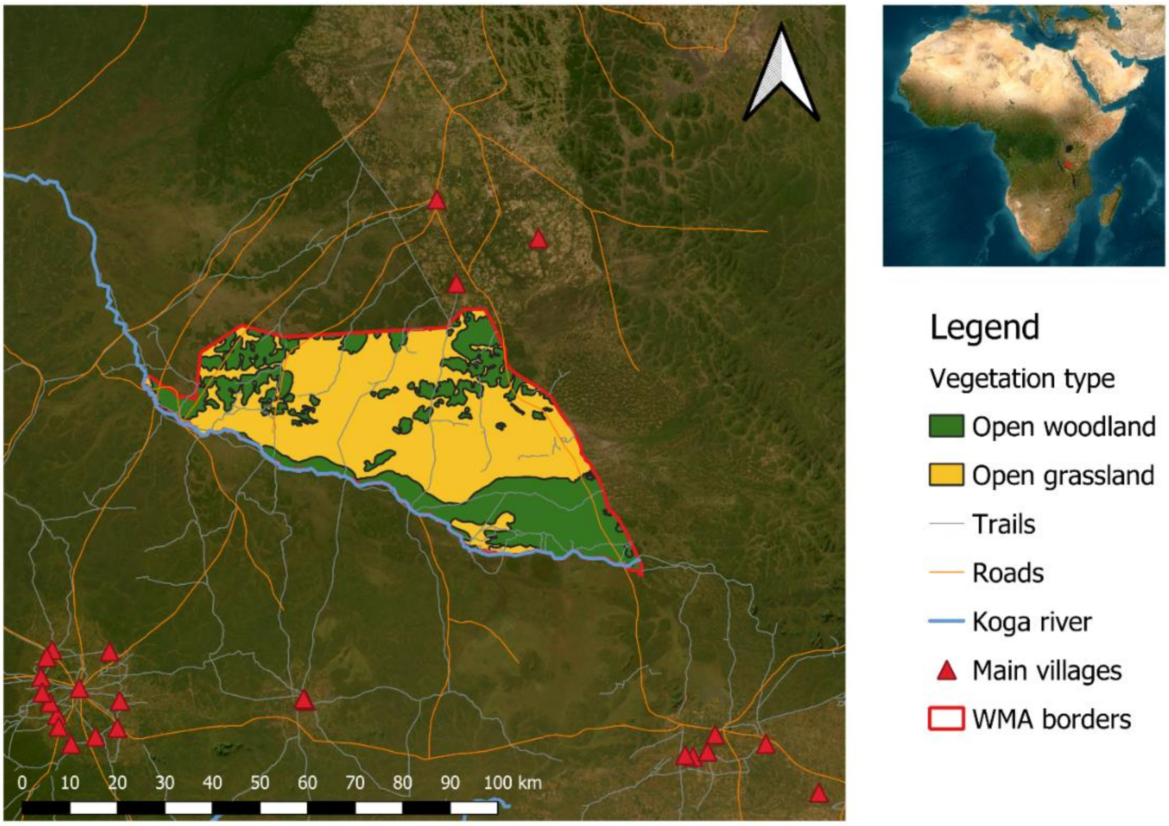


Fig. 1: Map showing the study site vegetation type, topography, and location of Ipole WMA, Tanzania 2022. The vegetation categories layer was produced in 1995 from satellite image classification.

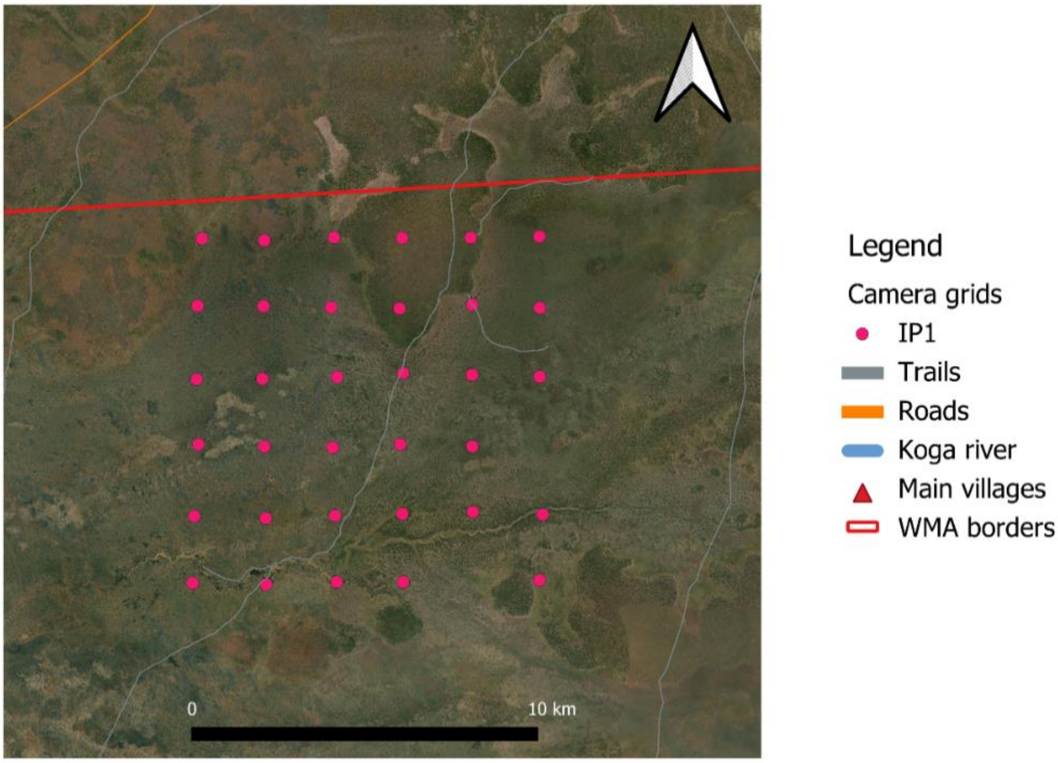


Fig. 2: Map of a sample study grid of Ipole WMA, Tanzania 2022, where each point represents a site where a camera trap had been set. Each camera trap location was separated by 2 km. The mesh of each quadrat is therefore 4 km^2 (2 km by 2 km).

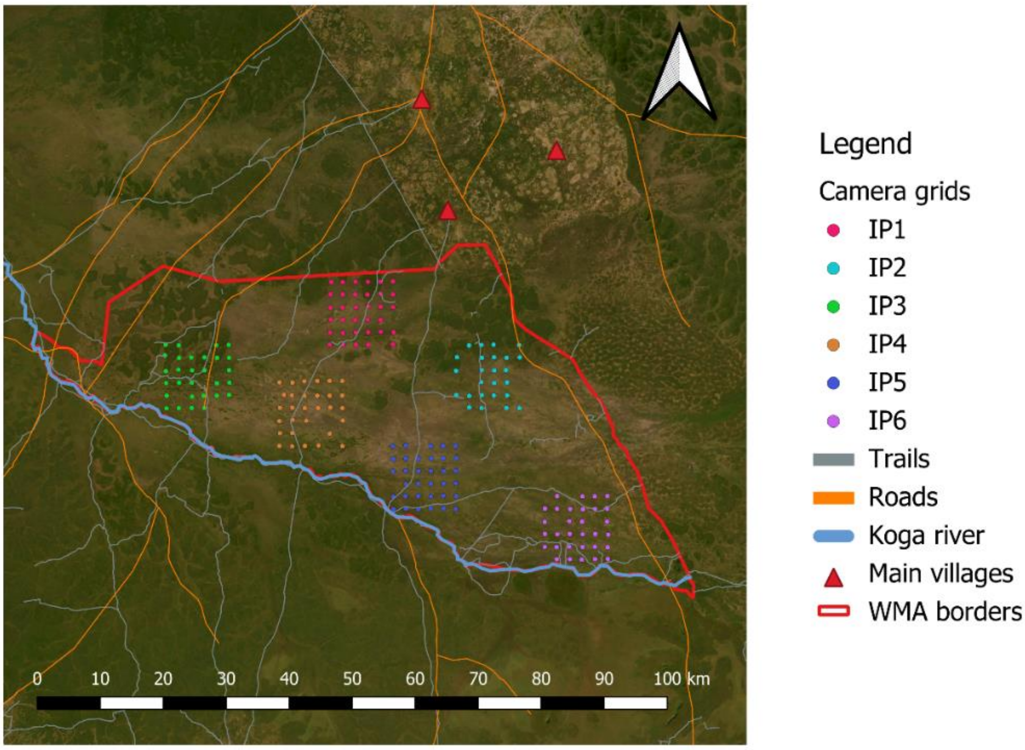


Fig. 3: Map of Ipole WMA, Tanzania 2022, showing the 183 camera sites used for analysis. 6 grids were deployed across the landscape, holding 36 cameras in each one. In the end, we did not use all cameras due to batteries or space issues.

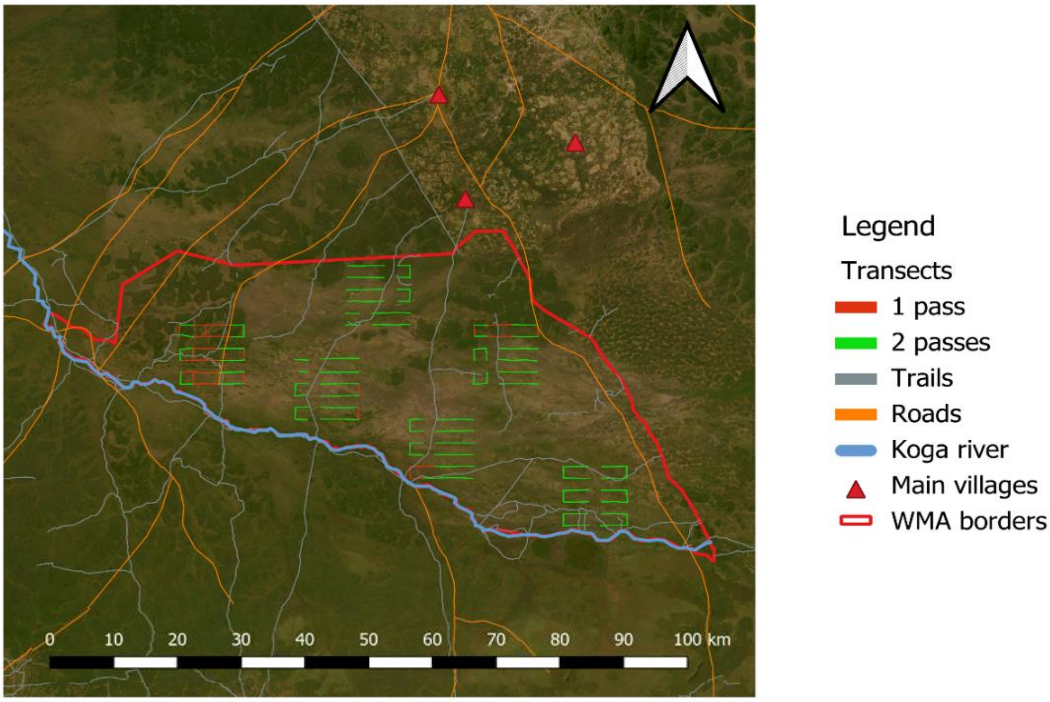


Fig. 4: Map of the transects walked by foot in between camera sites in Ipole WMA, Tanzania 2022. The green transects were done twice and the red transects were done once due to logistic issues.

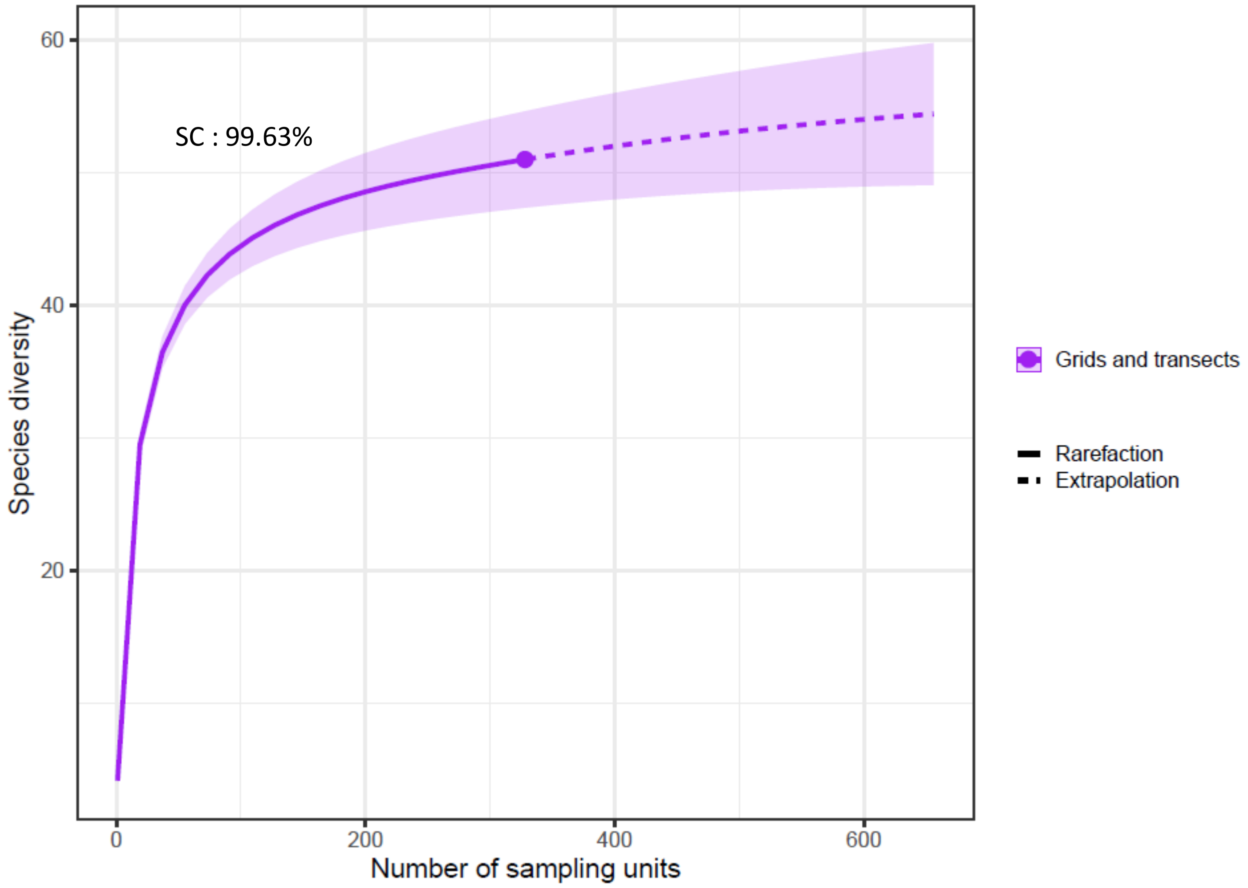


Fig. 5: Accumulation curve of transects across the 6 grids for the 153 considered transects and 183 considered camera traps. We reached 99.63% of sample coverage (SC) with 52 observed species across 336 sites.

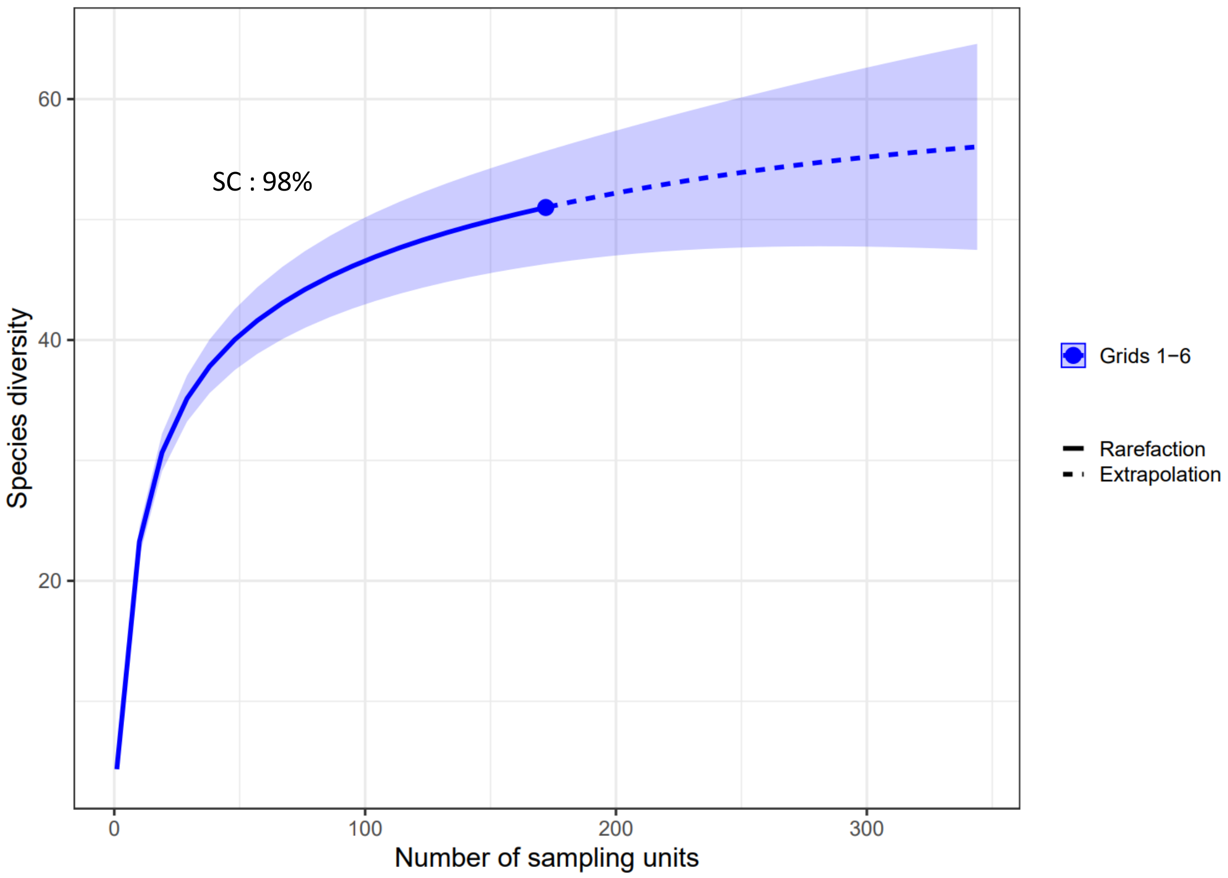


Fig. 6: Accumulation curve of camera sites across the 6 grids for the 183 considered camera sites. We reached 98% of sample coverage (SC) with 50 species detected across 183 sites over a 4-month period.

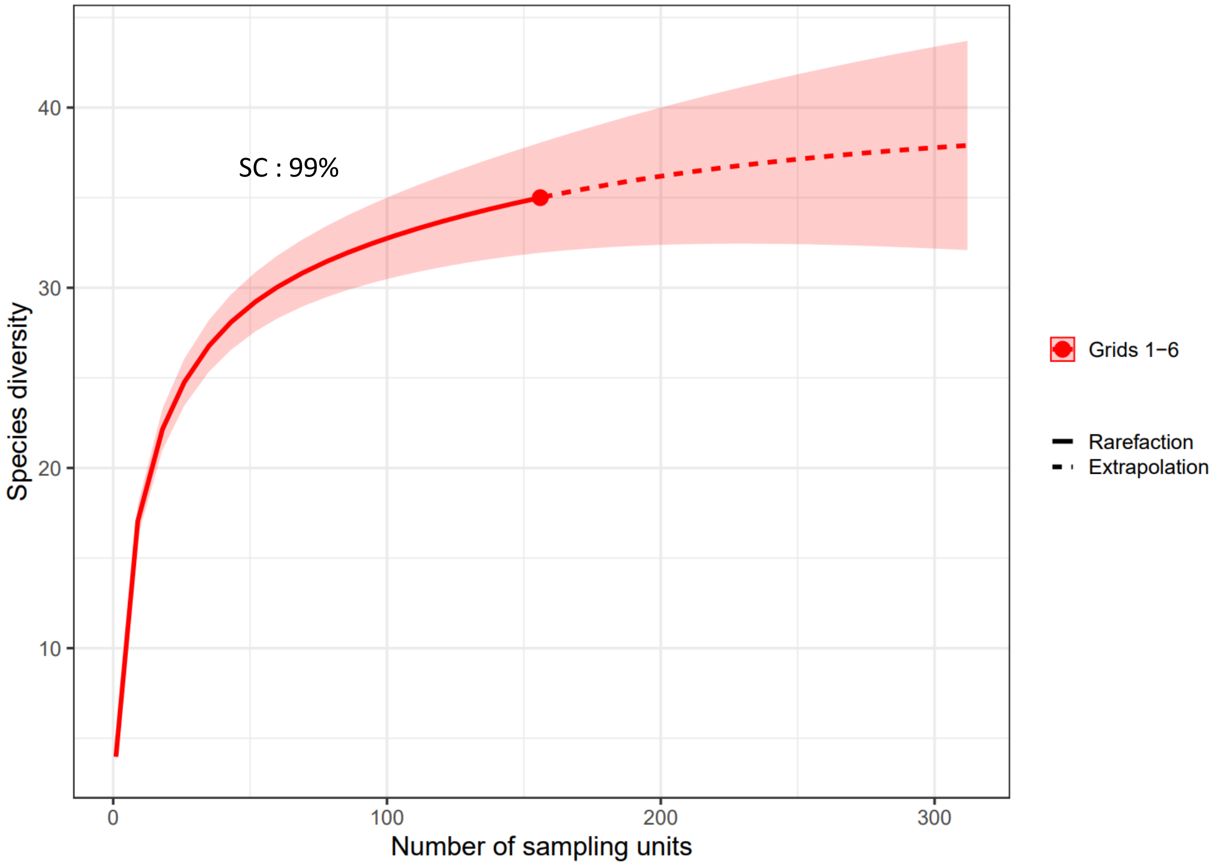


Fig. 7: Accumulation curve of transects across the 6 grids for the 153 considered transects. We reached 99% of sample coverage (SC) with 36 observed species across 153 transects with 2 passes.

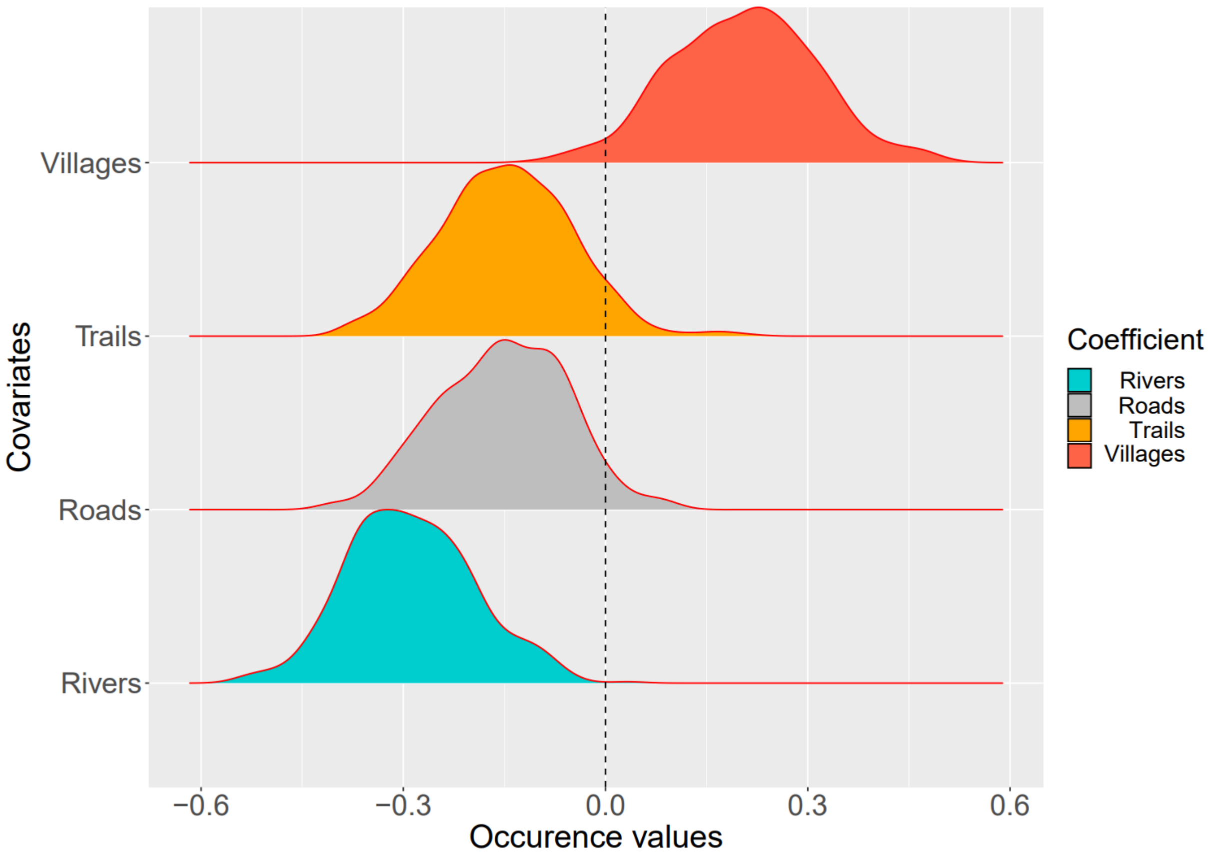


Fig. 8: Posterior distributions of the beta estimates representing correlations between community-level occupancy and distance to rivers, roads, trails and villages. The dashed line (h = 0) depicts the line of no-effect (above it, the correlation is positive, denoting an avoidance; below it, it is negative, denoting an attraction). The red lines indicate if >90% of the distribution is above or under zero.

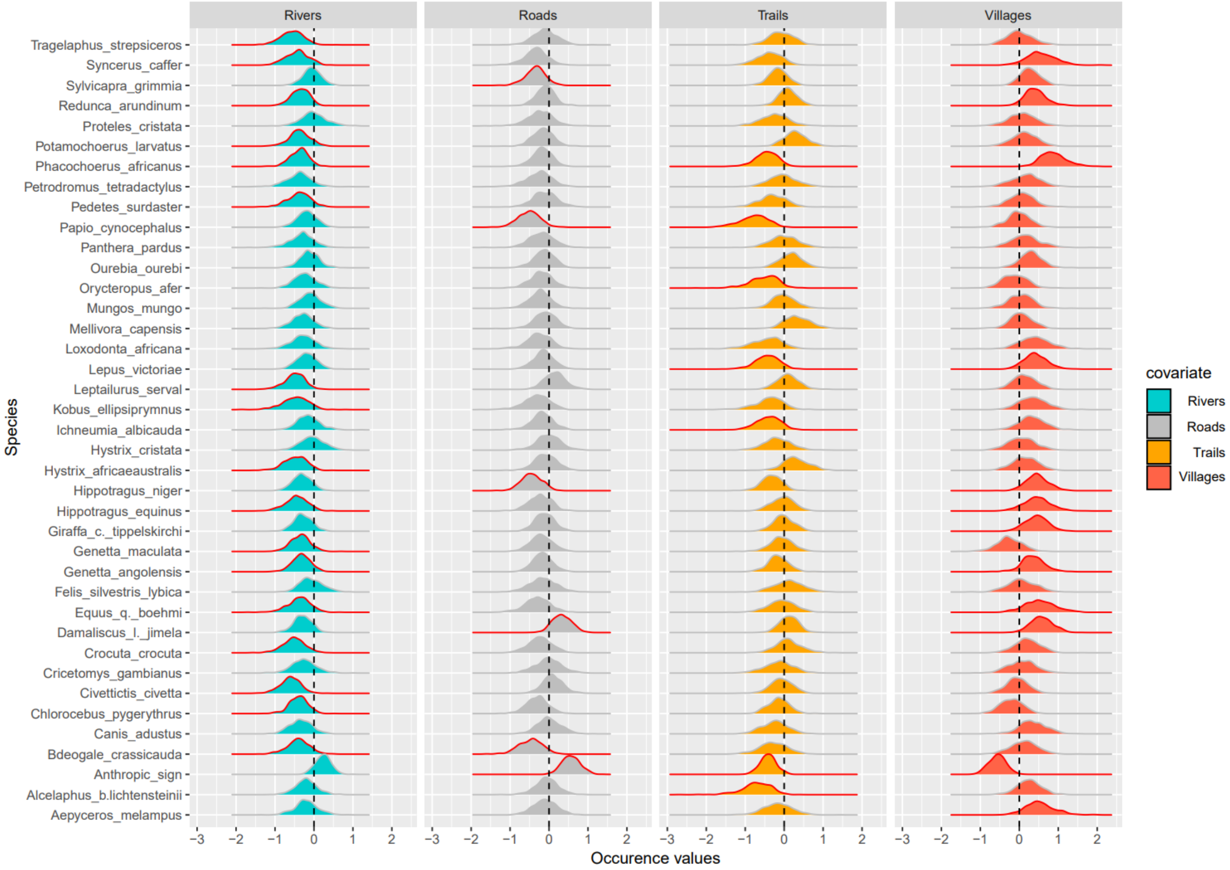


Fig. 9: Posterior distributions of the beta estimates representing correlations between species-level occupancy and distance to rivers, roads, trails and villages. The dashed line (h = 0) depicts the line of no-effect (above it, the correlation is positive, denoting an avoidance; below it, it is negative, denoting an attraction). The red lines indicate if >90% of the distribution is above or under zero.

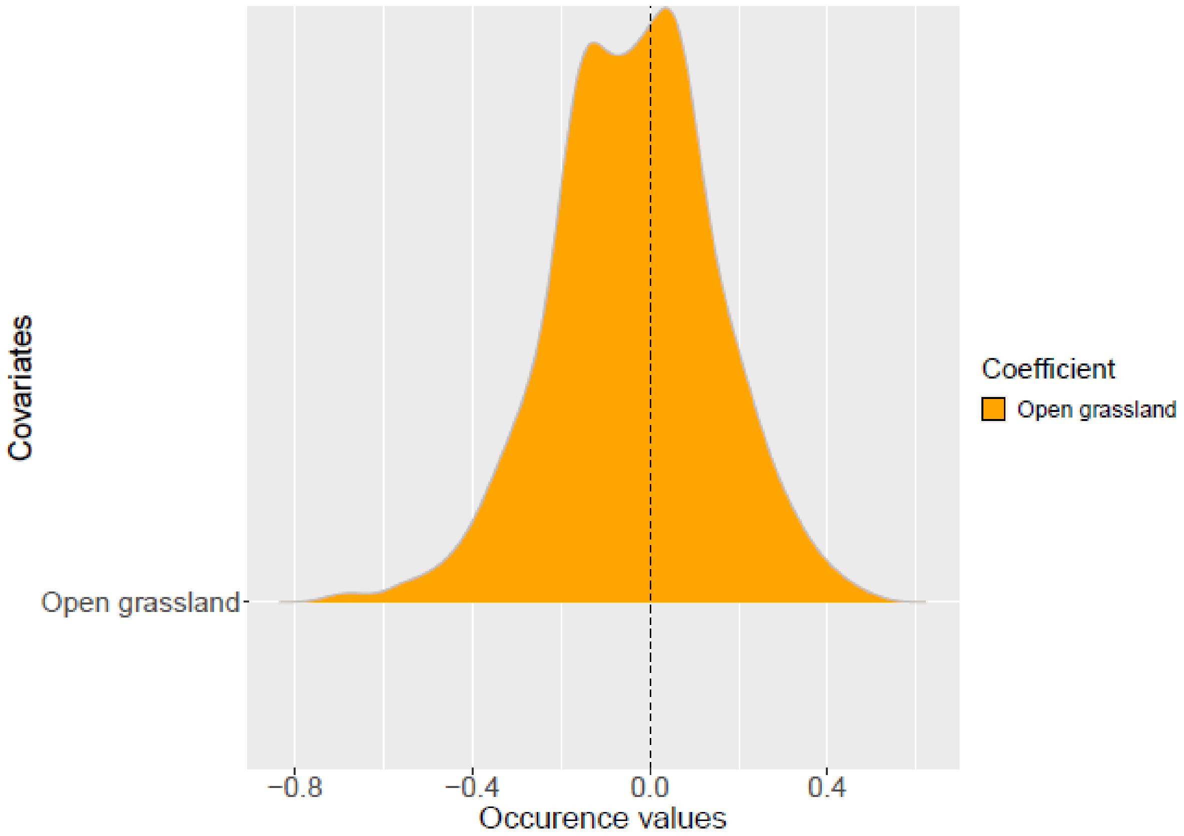


Fig. 10: Posterior distribution of the beta estimates representing correlation between community-level occupancy and the proportion of open grassland habitat surrounding a camera trap site. The dashed line (h = 0) depicts the line of no-effect (above it, the correlation is positive, below it, it is negative). The red lines indicate if >90% of the distribution is above or under zero.

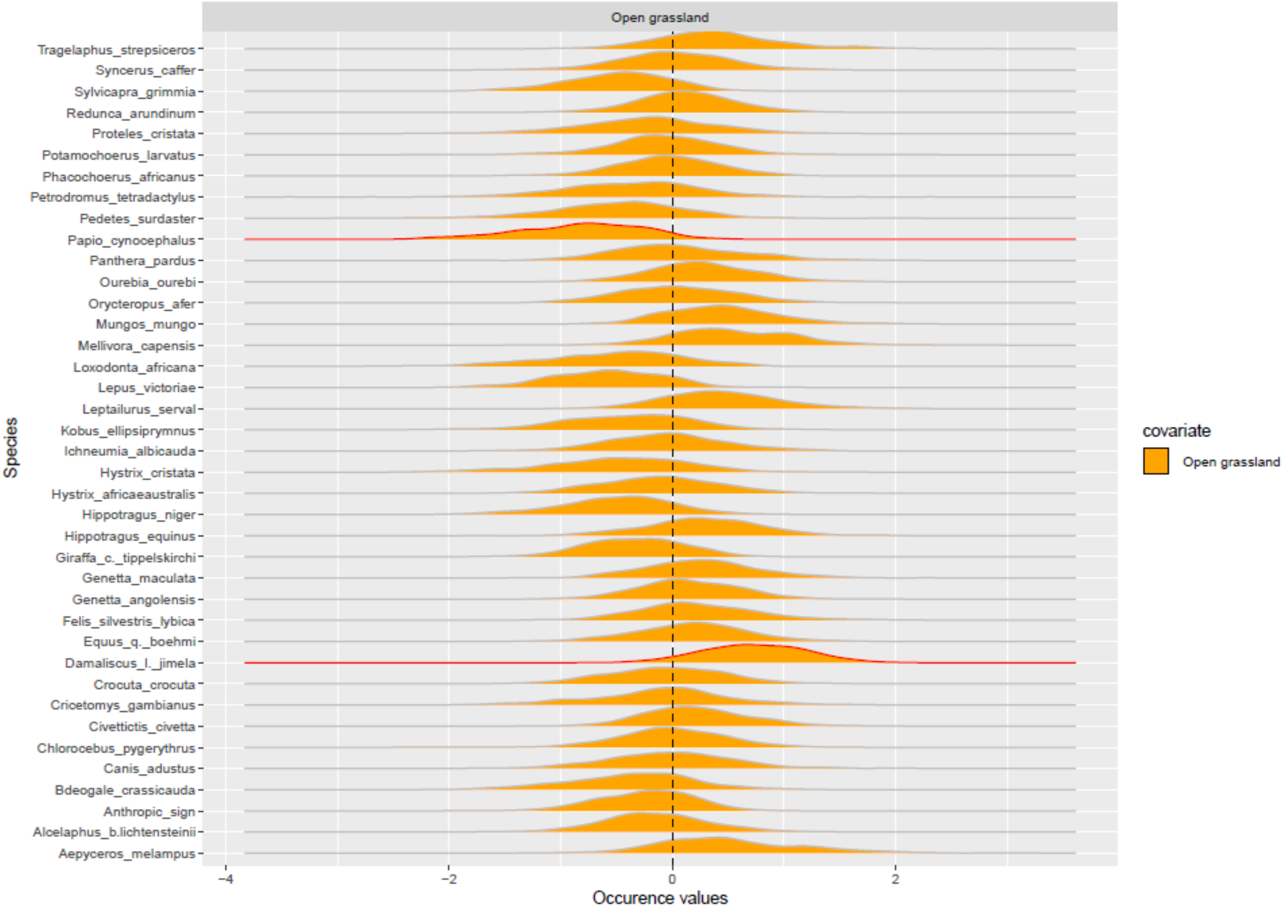


Fig. 11: Posterior distribution of the beta estimates representing correlation between species-level occupancy and the proportion of open grassland habitat surrounding a camera trap site. The dashed line (h = 0) depicts the line of no-effect (above it, the correlation is positive, below it, it is negative). The red lines indicate if >90% of the distribution is above or under zero.

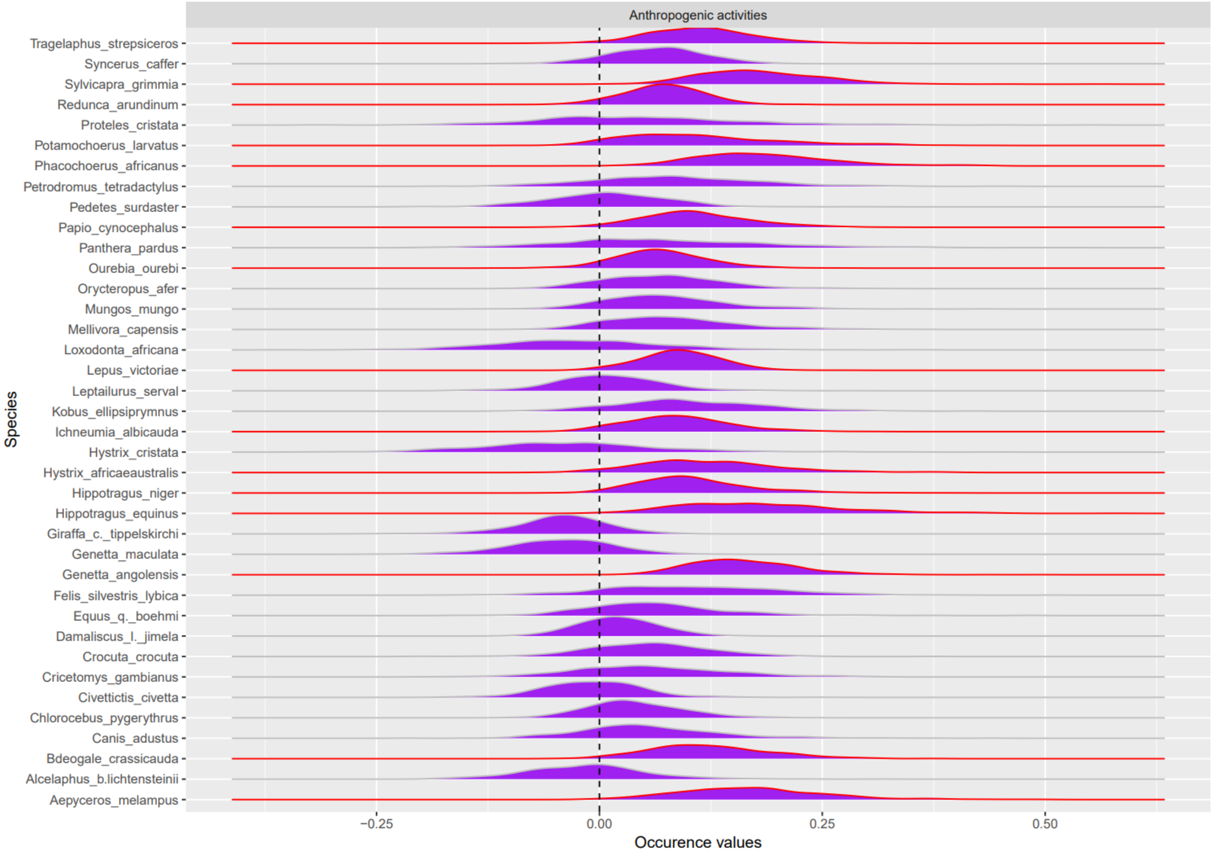


Fig. 12: Posterior distributions of the beta estimates representing correlations between species-level occupancy and distance to anthropogenic activities (livestock and human presence). The dashed line (h = 0) depicts the line of no-effect (above it, the correlation is positive, denoting an avoidance; below it, it is negative, denoting an attraction). The red lines indicate if >90% of the distribution is above or under zero.

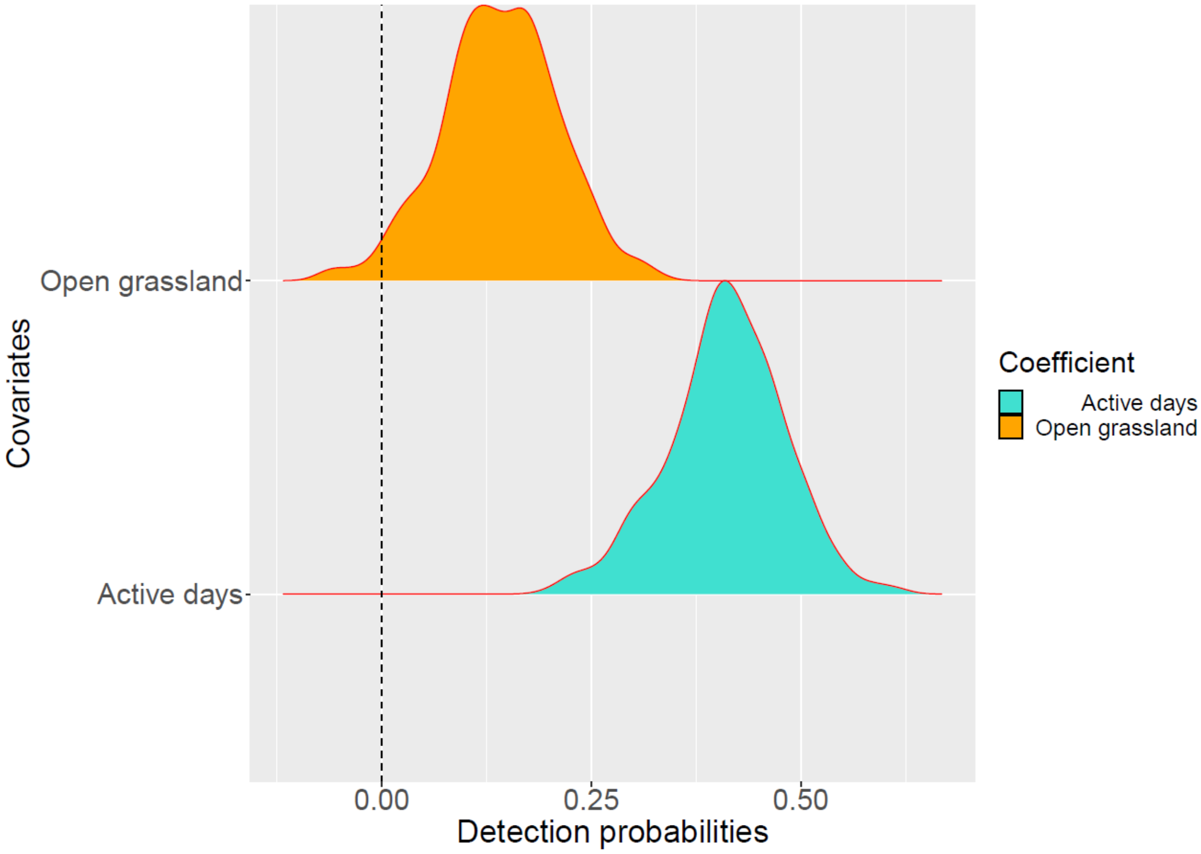


Fig. 13: Posterior distributions of beta estimates representing the correlation between community-level detection probabilities for the number of days a camera stayed active and the proportion of open grassland habitat around a camera site. The dashed line (h=0) depicts the line of no-effects (above it, the selection is positive, denoting an increase of detection with an increase of active days or an increase or open grassland proportion around a camera site; below it, it is negative, denoting a decrease of detection with an increase of active days or an increase of detection with a decrease of open grassland proportion around the camera site). The red lines indicate if >90% of the distribution is above or under zero.

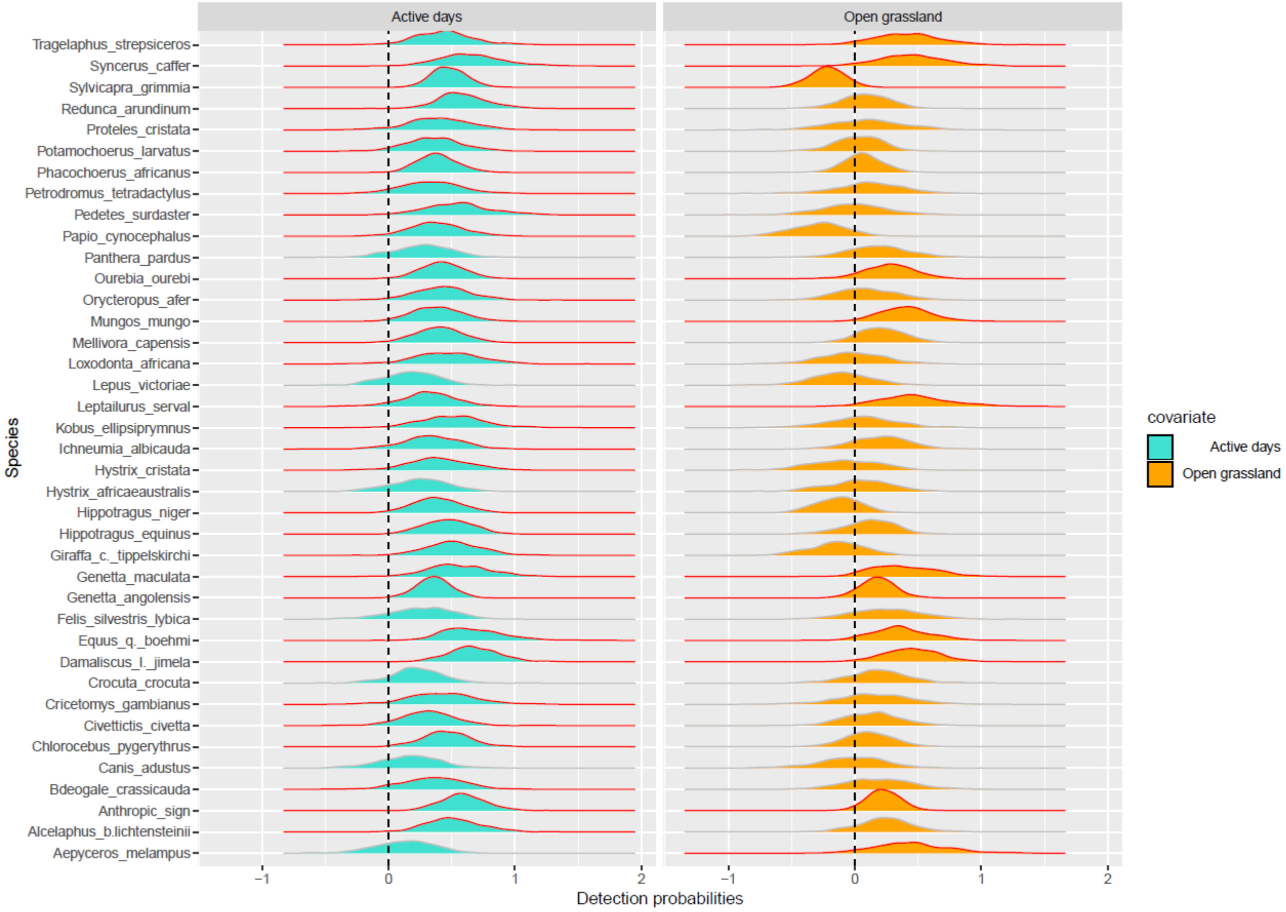


Fig. 14: Posterior distributions of beta estimates representing the correlation between species-level detection probabilities for the number of days a camera stayed active and the proportion of open grassland habitat around a camera site. The dashed line (h=0) depicts the line of no-effects (above it, the selection is positive, denoting an increase of detection with an increase of active days or an increase or open grassland proportion around a camera site; below it, it is negative, denoting a decrease of detection with an increase of active days or an increase of detection with a decrease of open grassland proportion around the camera site). The red lines indicate if >90% of the distribution is above or under zero.

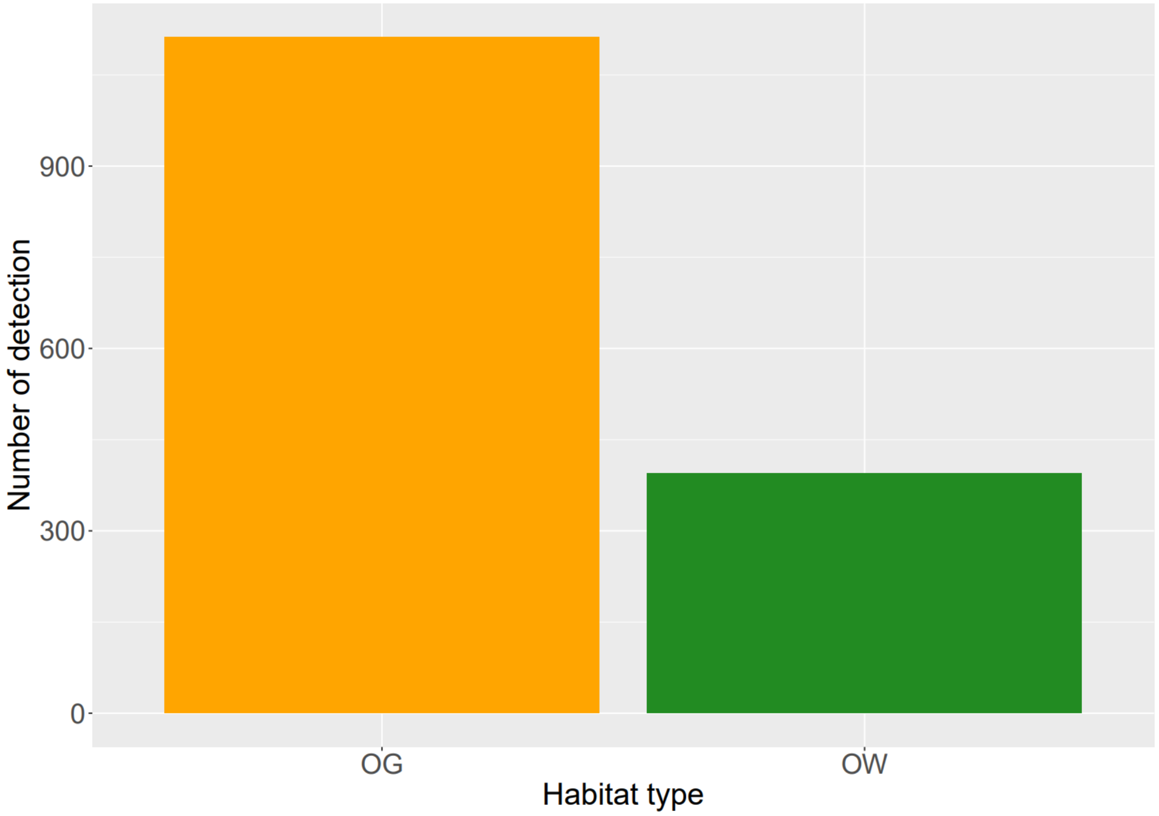


Fig. 15: Total detections across all species when detected in open grassland habitat (OG) or open woodland habitat (OW).

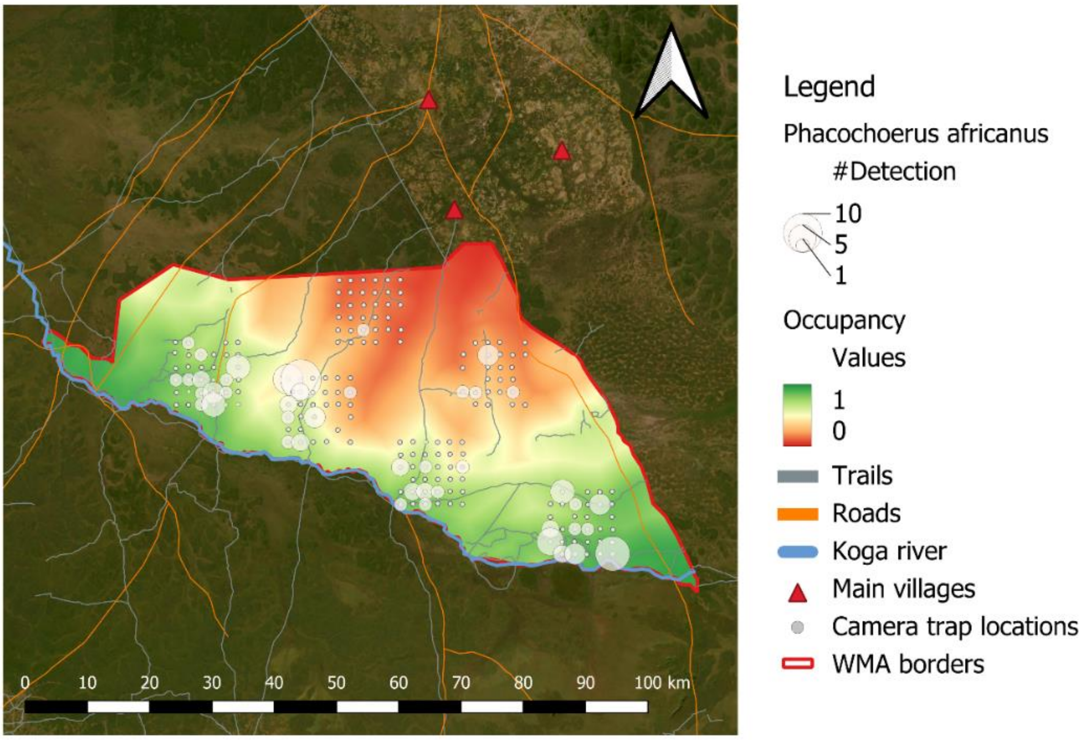


Fig. 16: Map of predicted occupancy values for the African warthog (*Phacochoerus africanus*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected.

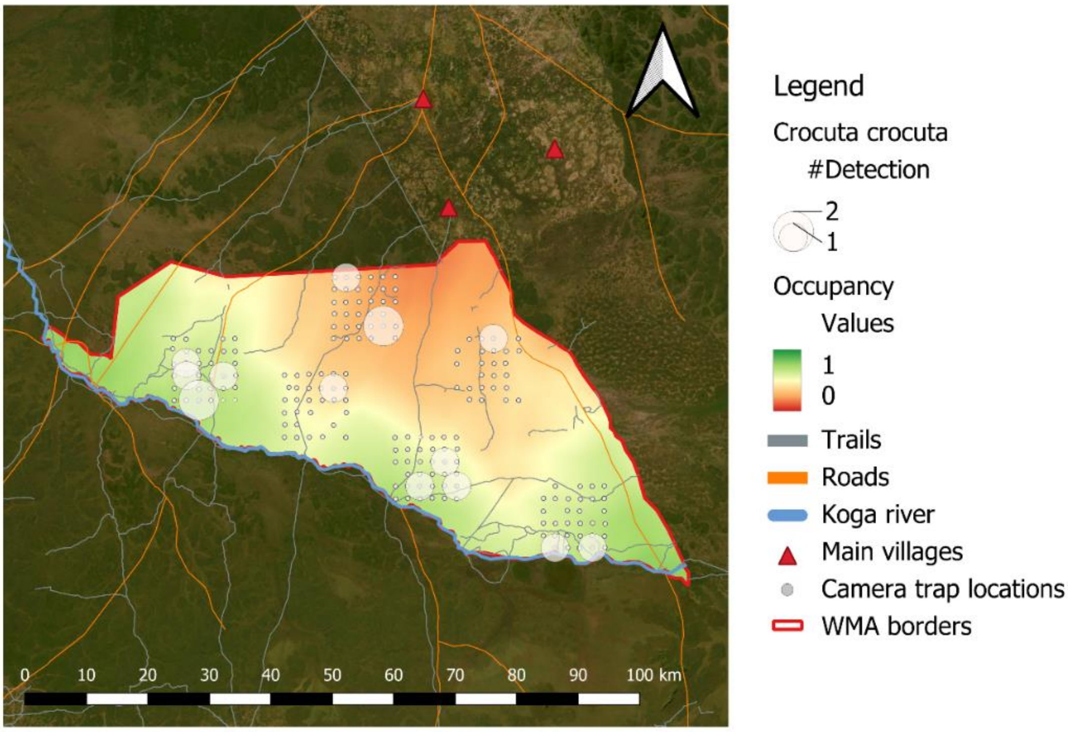


Fig. 17: Map of predicted occupancy values for the spotted hyena (*Crocuta Crocuta*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected. This distribution is representative of various species occupancy models such as *Leptailurus serval, Tragelaphus strepsiceros, Potamochoerus larvatus, Pedestes surdaster, Kobus ellipsiprymnus, Hystrix africaeaustralis, Genetta maculate, Civettictis civetta,* and *Chlorocebus pygerythrus.*

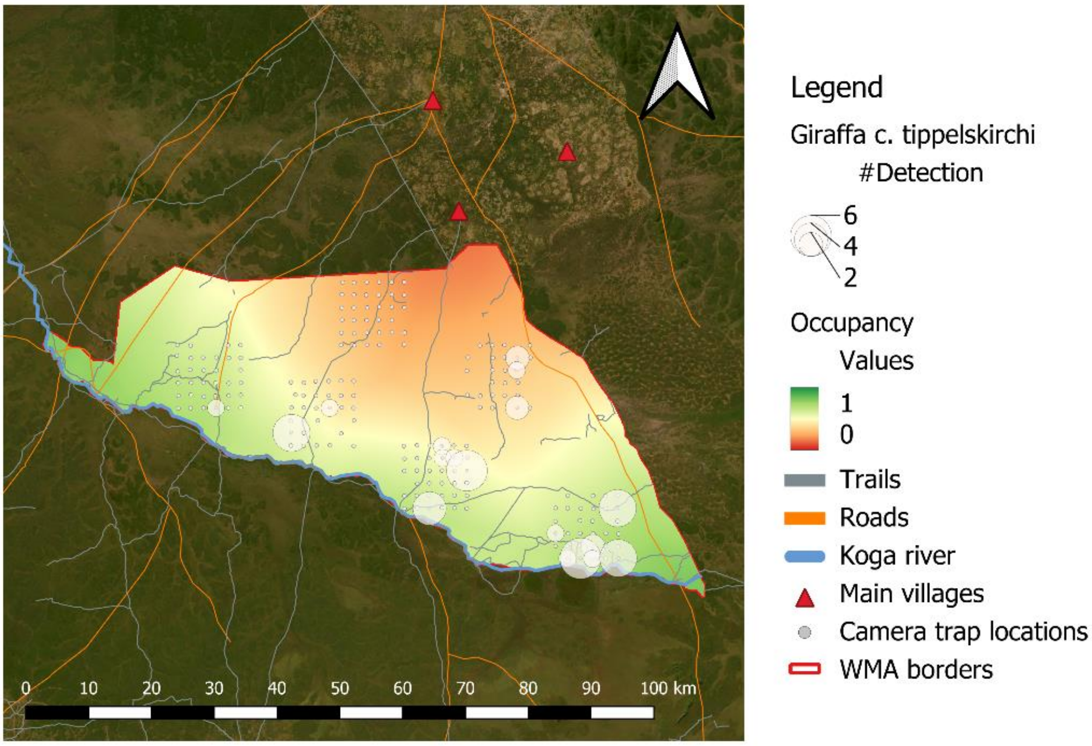


Fig. 18: Map of predicted occupancy values for the Masai giraffe (*Giraffa c. tippelskirchi*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected. This distribution is representative of various species occupancy models such as *Aepyceros melampus***.**

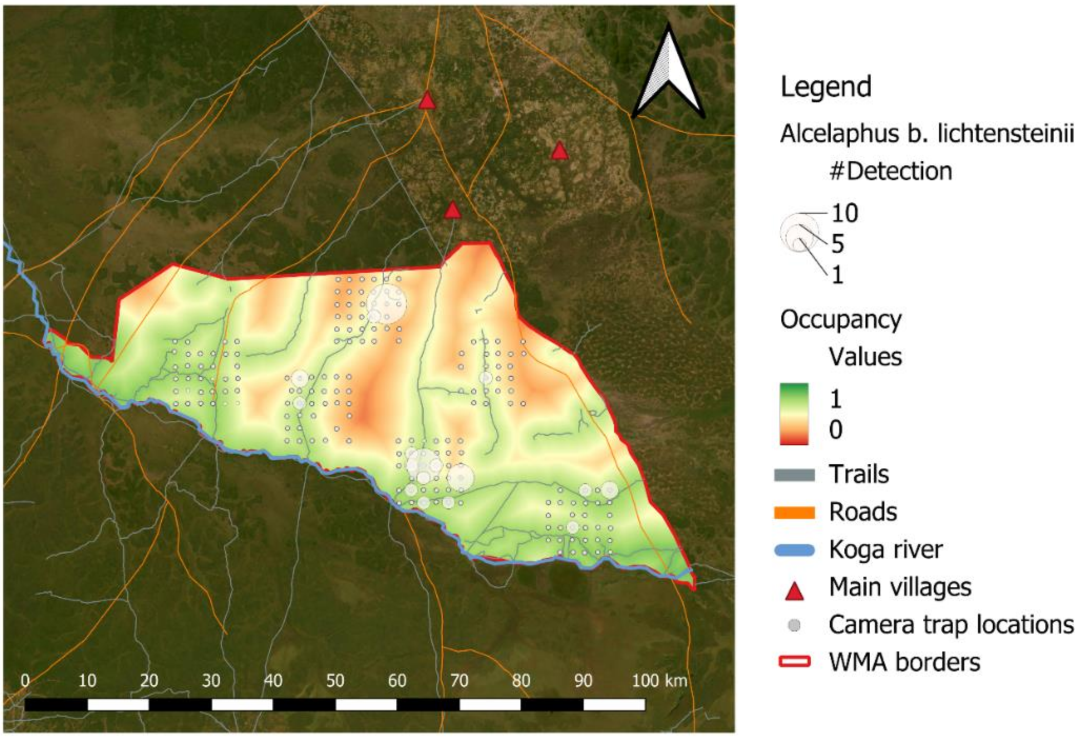


Fig. 19: Map of predicted occupancy values for the Lichtenstein's hartebeest (*Alcelaphus b. lichtensteinii*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected. This distribution is representative of various species occupancy models such as *Ichneumia albicauda,* and *Orycteropus afer*.

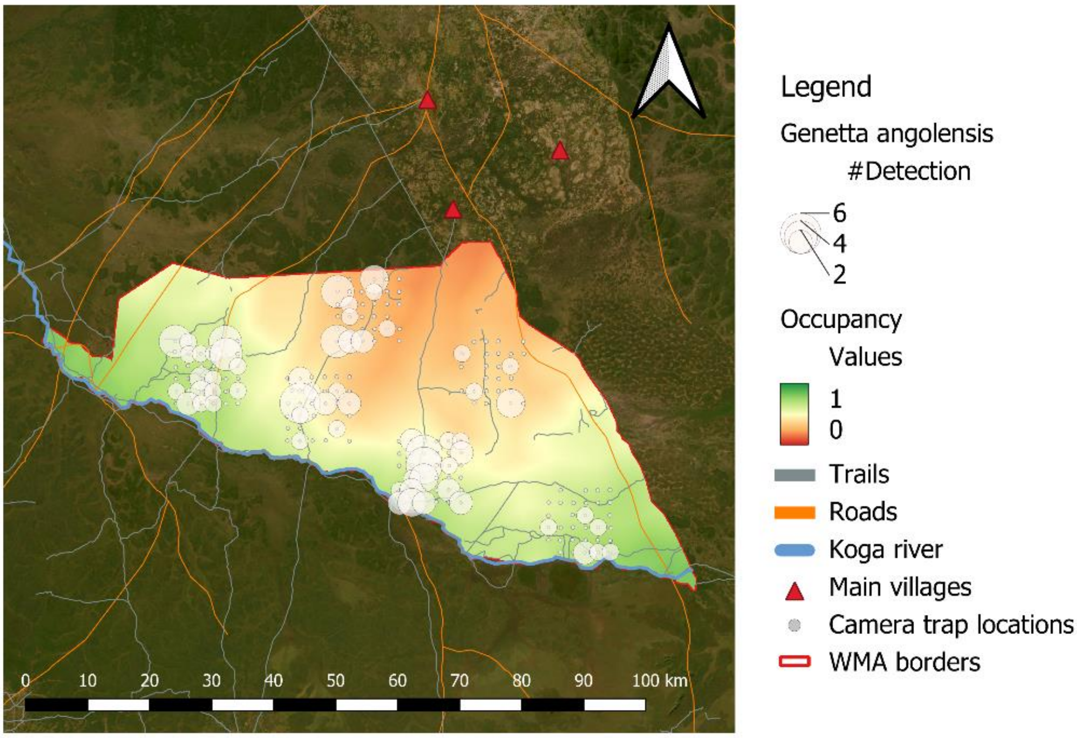


Fig. 20: Map of predicted occupancy values for the Angolan genet (*Genetta angolensis*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected. This distribution is representative of various species occupancy models such as *Syncerus caffer, Redunca arundinum, Hippotragus equinus,* and *Equus q. boehmi*.

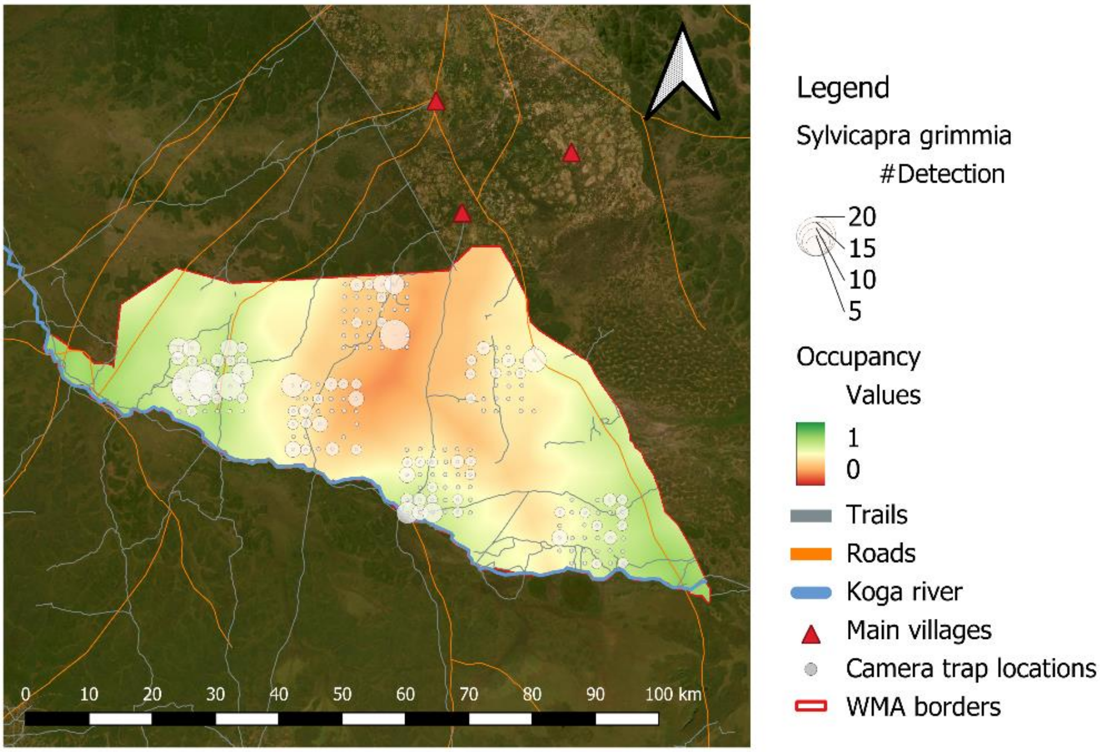


Fig. 21: Map of predicted occupancy values for the common duiker (*Sylvicapra grimmia*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected.

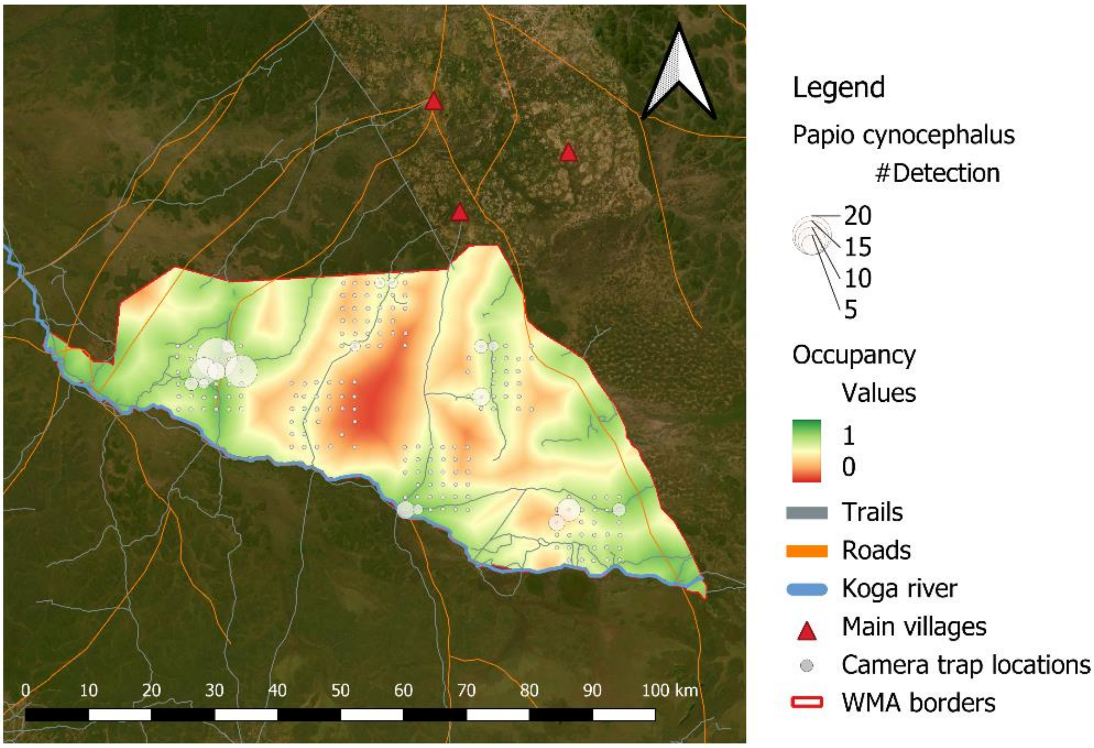


Fig. 22: Map of predicted occupancy values for the yellow baboon (*Papio cynocephalus*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected.

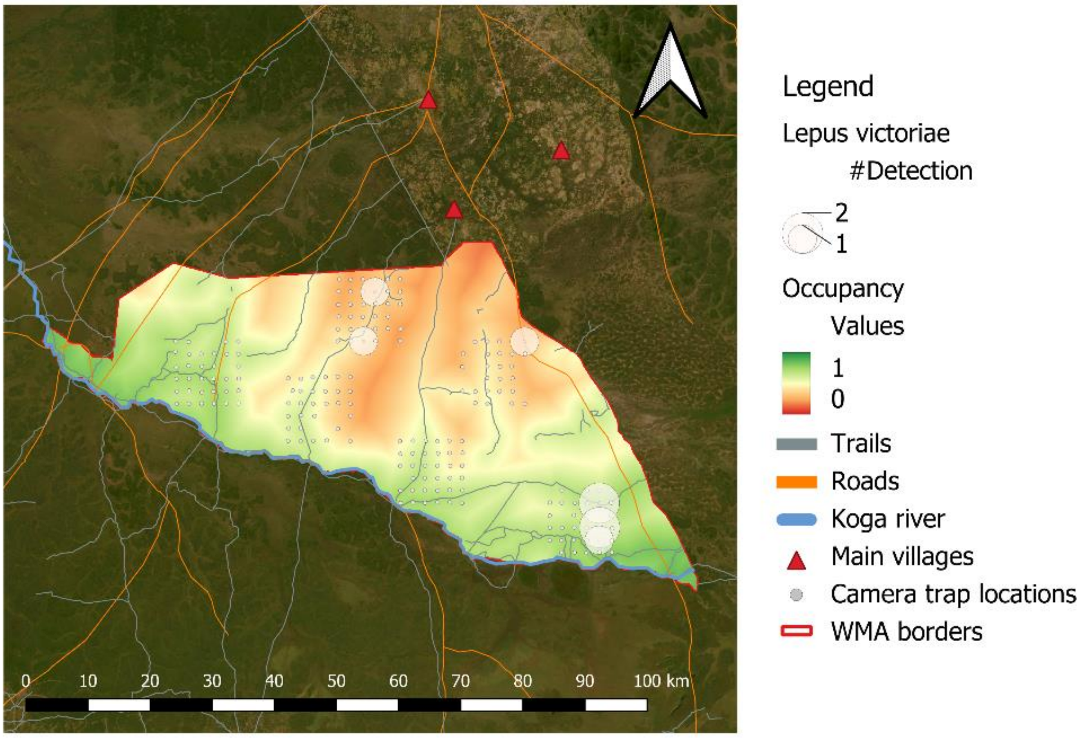


Fig. 23: Map of predicted occupancy values for the African hare (*Lepus victoriae*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected.

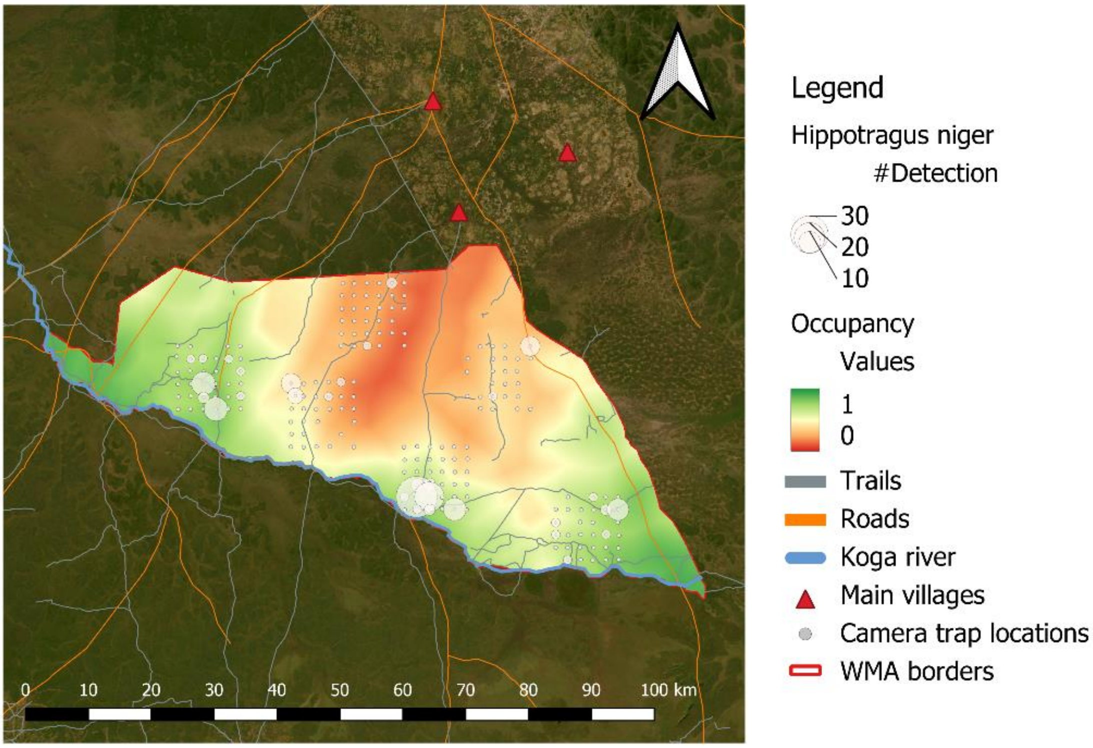


Fig. 24: Map of predicted occupancy values for the sable antelope (*Hippotragus niger*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected.

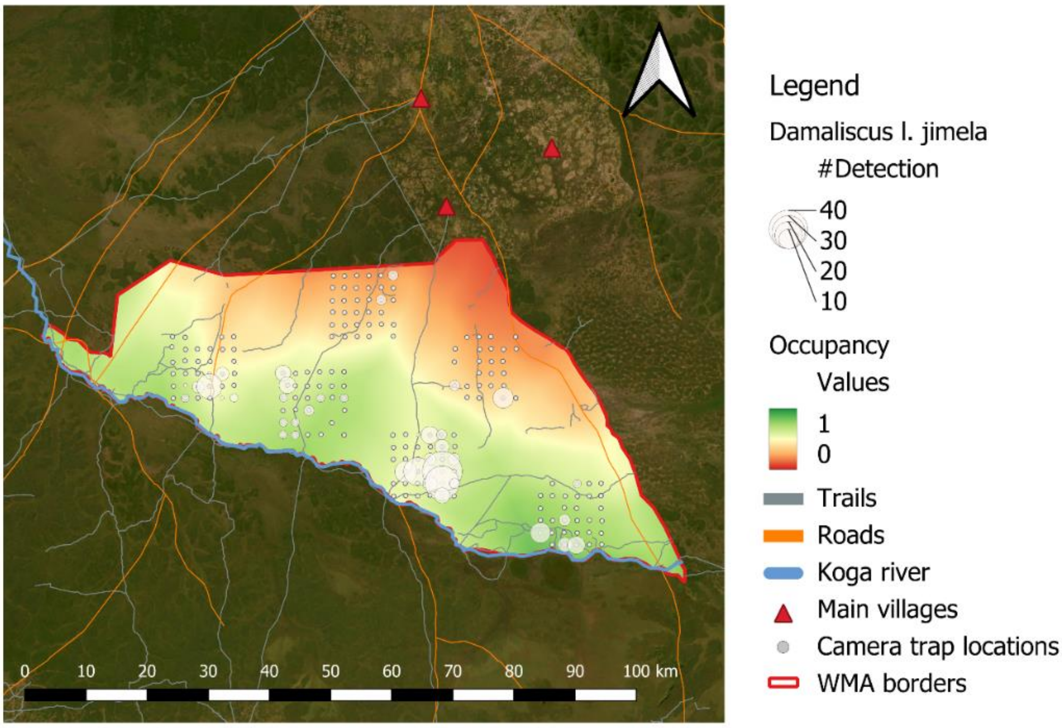


Fig. 25: Map of predicted occupancy values for the Topi (*Damaliscus l. jimela*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected.

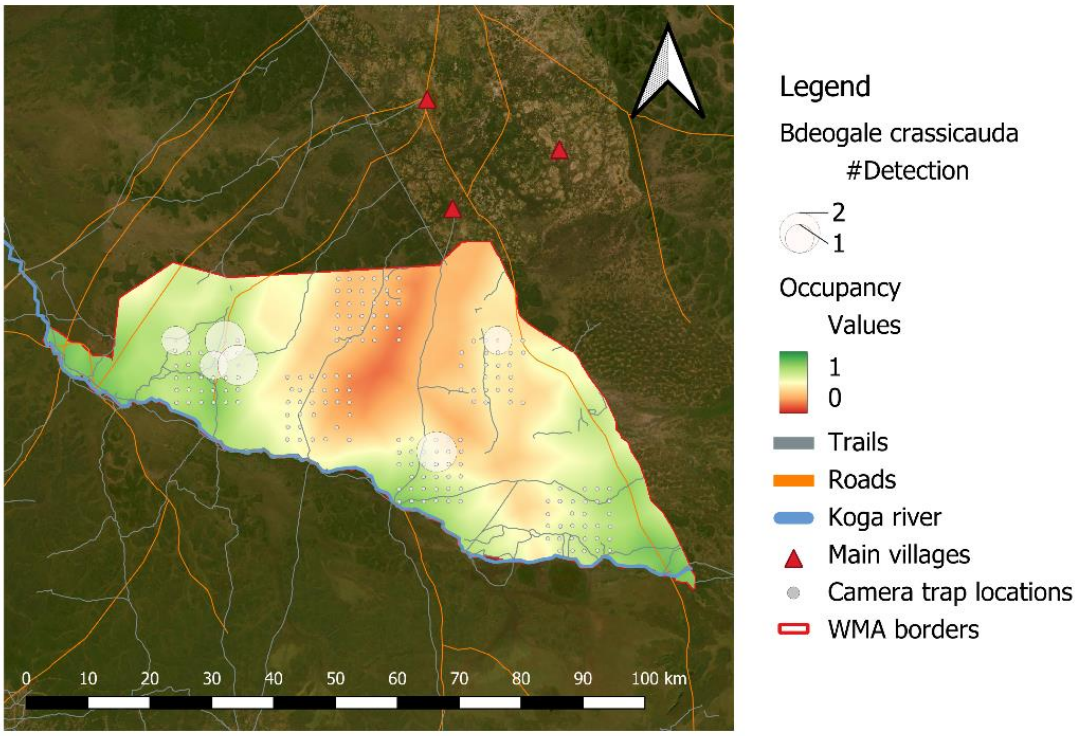


Fig. 26: Map of predicted occupancy values for the bushy-tailed mongoose (*Bdeogale crassicauda*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected.

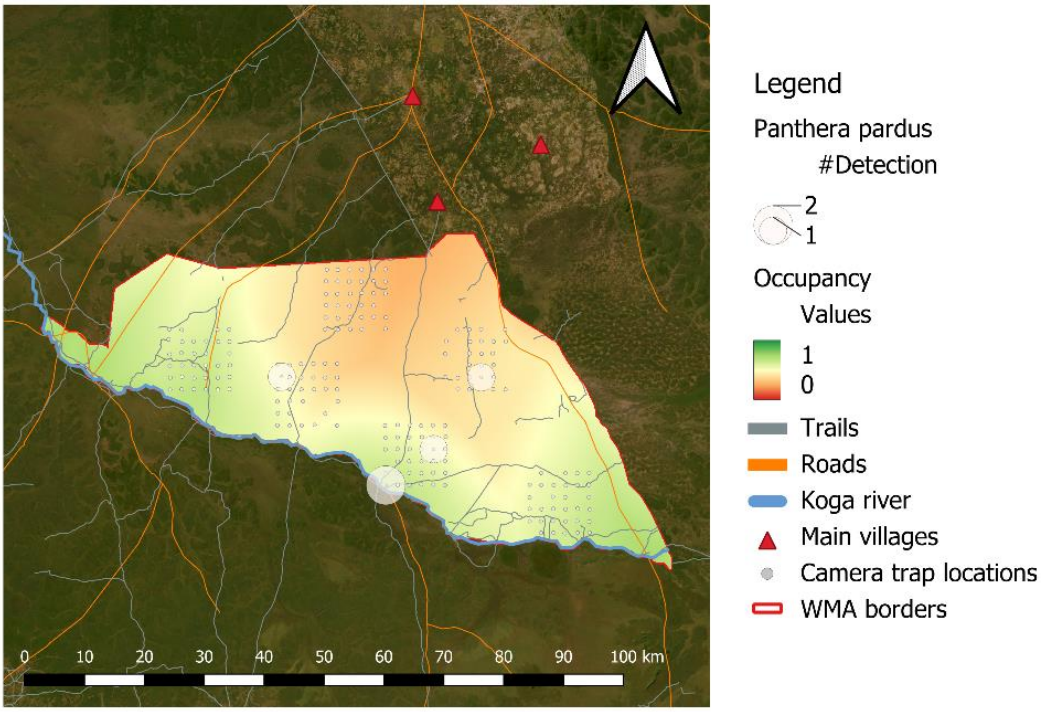


Fig. 27: Map of predicted occupancy values for the African leopard (*Panthera pardus*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the species was detected, its size indicates the number of times it was detected. This distribution is representative of various species occupancy such as *Proteles cristata, Petrodromus tetradactylus, Ourebia ourebi, Mungos mungo, Mellivora capensis, Loxodonta Africana, Hystrix cristata, Felis silvestris lybica, Cricetomys gambianus,* and *Canis adustus.*

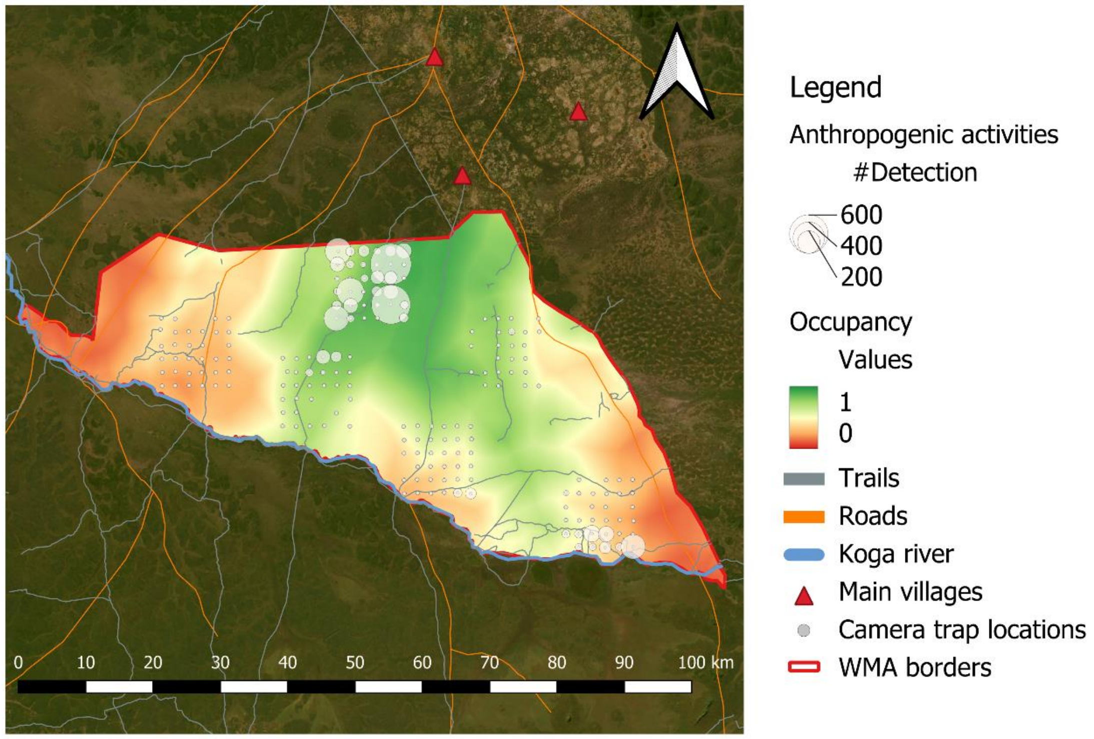


Fig. 28: Map of predicted occupancy values for the anthropogenic activities (it includes humans, dogs, sheep, cows, and donkeys), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The circles are locations where the livestock was detected, its size indicates the number of times it was detected.

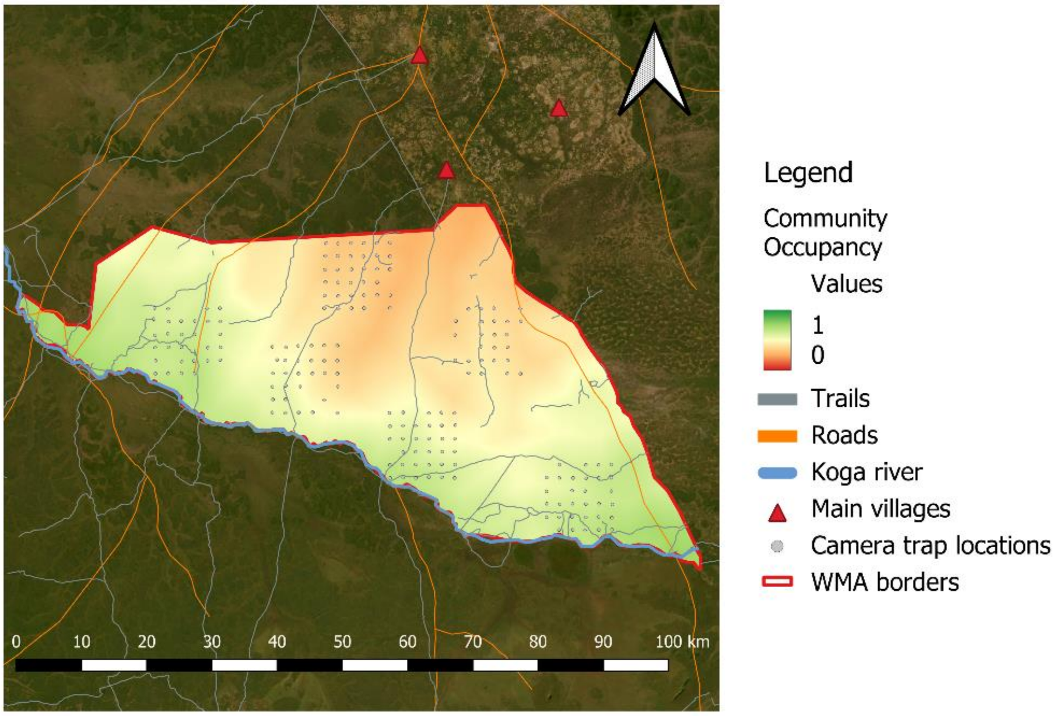


Fig. 29: Map of predicted occupancy values for the overall community of detected species, extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites).

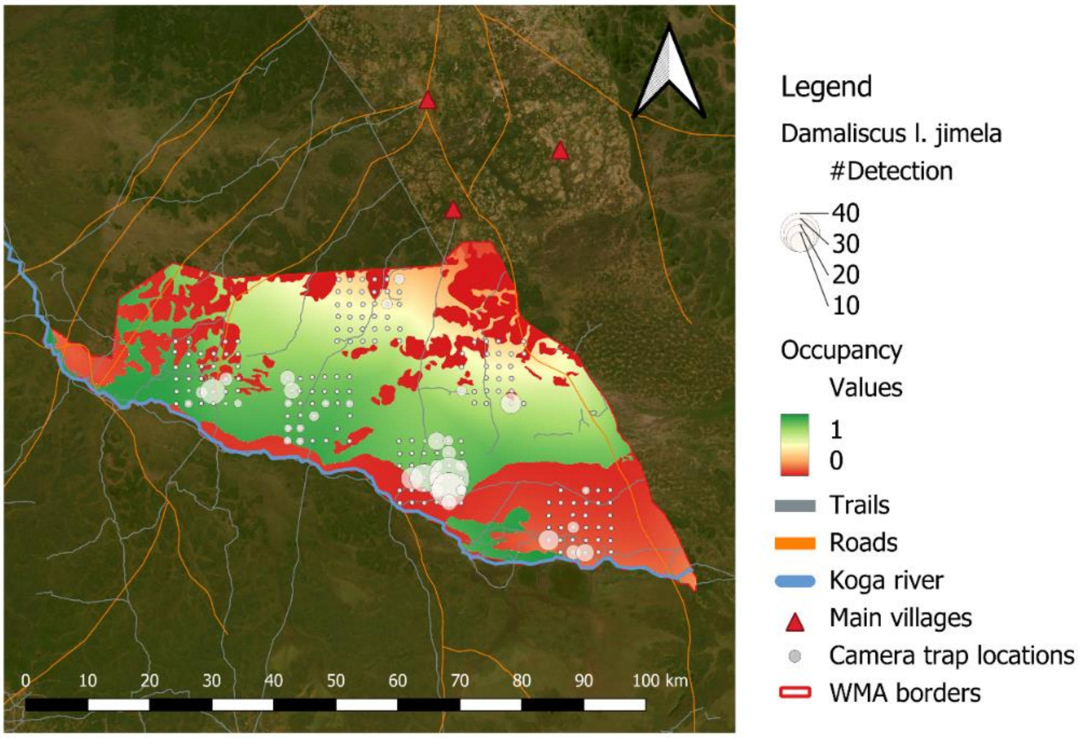


Fig. 30: Map of predicted occupancy values for the Topi (*Damaliscus l. jimela*), extracted from spatial occupancy model output. Values range from 0 (unoccupied sites) to 1 (heavily occupied sites). The red areas on the map have a 0-occupancy value, they represent the open woodland habitat that is not a favored vegetation type for this species. The circles are locations where the species was detected, its size indicates the number of times it was detected. The occupancy of the species is calculated with environmental distances, and vegetation proportion.

Fig. 31: Photo of a water pit dug by shepherds to provide water access for their livestock.

Declaration of consent

on the basis of Article 30 of the RSL Phil.-nat. 18

Name/First Name: Novovitch Lucy Helena

Registration Number: 16-407-207

Study program: Master of Science in Ecology and Evolution

Bachelor ☐ Master ☑ Dissertation ☐

Title of the thesis: Assessing the impact of human disturbance on mammal distributions within a community conservation area in east Africa

Supervisor: Dr. Ian Ausprey and Prof. Dr. Raphaël Arlettaz

I declare herewith that this thesis is my own work and that I have not used any sources other than those stated. I have indicated the adoption of quotations as well as thoughts taken from other authors as such in the thesis. I am aware that the Senate pursuant to Article 36 paragraph 1 litera r of the University Act of 5 September, 1996 is authorized to revoke the title awarded on the basis of this thesis.

For the purposes of evaluation and verification of compliance with the declaration of originality and the regulations governing plagiarism, I hereby grant the University of Bern the right to process my personal data and to perform the acts of use this requires, in particular, to reproduce the written thesis and to store it permanently in a database, and to use said database, or to make said database available, to enable comparison with future theses submitted by others.

Bern, den 22. August 2023

Place/Date

Signature