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MAMMALS OF THE RUNGAN–KAHAYAN LANDSCAPE, CENTRAL KALIMANTAN, INDONESIA

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Abstract
The Rungan – Kahayan landscape, covering ~4700 km^2 in Central Kalimantan is a diverse mosaic of tropical heath (*kerangas*) and peat swamp forests. The mammal fauna of this region remains poorly documented, while the area has been subjected to rapid land cover changes threatening remaining forest areas. Here we describe the medium–large-sized mammal community in eight community-managed forest blocks and one forest area set aside for education purposes in this landscape. We deployed 86 camera traps across seven habitat types between April 2022 and October 2023, intending to set baselines on mammal presence and distribution within the landscape. We recorded 936 independent detections of 24 species through camera trap surveys, comprising six mammalian orders distributed across 14 families, including three taxa endemic to Borneo. Forest gaps and kerangas habitats recorded the highest independent detections per unit area, despite low-pole and mixed-swamps being the most widespread habitat type. The presence of several protected species, including the first detection of otter-civet (*Cynogale bennettii*) in this area, emphasises the conservation significance of the remaining forests within the landscape. The lesser mouse deer (*Tragulus kanchil*) and the muntjac (*Muntiacus artherodes*) were frequently detected. The sambar deer (*Rusa unicolor*) and bearded pig (*Sus barbatus*)—common ungulates in lowlands, typically hunted—were rare. Our study represents the first large-scale baseline assessment of mammals in the Rungan-Kahayan landscape, highlighting its significance for animal conservation in Central Kalimantan.

Keywords: Borneo, occupancy, relative abundance, sampling effort, species inventory, Southeast Asia

Introduction

The observed rapid decline in biodiversity, especially among large vertebrates across the tropics, emphasises the need to establish baselines for wildlife communities in fragmented, anthropogenically impacted, and unprotected areas (Monsarrat *et al*. 2019). Accurate monitoring and assessment of biodiversity inform effective wildlife management and provide a foundation for evaluating factors impacting biodiversity. Biodiversity inventories are important to understanding patterns in species richness, diversity, and community compositions across different sites, habitat types, and forest conditions (Tobler *et al*. 2008).

Advancements in technology have greatly enhanced biodiversity monitoring, overcoming challenges associated with traditional methods, such as direct observation or live trapping, which are labour-intensive, costly, and ethically challenging (Meek *et al*. 2014). Among these innovations, camera trapping has emerged as a popular method to survey wildlife for behavioural and population studies (Cutler *et al*. 1999, O'Connell & Nichols 2011), especially for data-deficient and elusive species (Kucera & Barrett 2011). The main benefits of camera trapping are that they provide a non-invasive, economical, and more ethical alternative for testing theories related to wildlife that is mostly free of observer bias (Zett *et al*. 2022). Camera trapping is frequently used to assess wildlife community metrics (Tobler *et al*. 2008), densities (Karanth & Nichols 1998), and population abundance indices (O'Brien *et al*. 2011), as well as being used for taxonomic inventories (Swann & Perkins 2013), and conservation assessments (Burton *et al*. 2015).

While camera trapping has limitations such as the infectivity in accounting for niche partitioning of species, e.g. arboreality (Moore *et al*. 2020), imperfect detections of species (Burton *et al*. 2015, Sollman *et al*. 2024), and different deployment strategies, this technique has proven to be highly effective for biodiversity surveys in areas where long-term studies via direct observation and live-trapping are logistically challenging.

Mammals are commonly surveyed taxa as they comprise rich communities of species from a variety of trophic groups and a wide range of body sizes (Ahumada *et al*. 2011), which play different roles in ecosystem functioning. Several species of mammals are also regarded as umbrella species, where their large area requirements co-distributed with other taxa often correlate with broader biodiversity patterns (Caro 2010, Ardiantiono *et al*. 2024). Medium to large-sized mammals in tropical forests are also given priority in many studies as they represent a functionally diversified component of forest quality, although are universally threatened by hunting, habitat loss, and fragmentation (Gardner *et al*. 2019). Hence adequate knowledge of the presence and distribution of these species is important for planning, implementing, and evaluating conservation strategies in a region (Tobler *et al*. 2008).

Despite significant focus on conservation-related research in Kalimantan, the Indonesian part of the island of Borneo, there are few mammal inventories and information is still lacking on the distribution of species across the island. Existing camera-trapping studies have been limited in scope and geographical coverage in Kalimantan (Rustam *et al*. 2012, Wahyudi *et al*. 2013, Cheyne *et al*. 2016, Higashide *et al*. 2018), leaving substantial gaps in our understanding of wildlife outside strictly protected areas.

To address this gap, we conducted a mammal survey using camera traps in a forest block of the Rungan-Kahayan landscape, in the province of Central Kalimantan. This landscape is both complex and unique. Ecologically, it is characteristic of a mosaic of habitat types comprising peatlands in the south to the drier lowland mixed-dipterocarp dominated forests in the north, interspersed by several other types in between, including tropical heath forests (*kerangas*) in the central part of the landscape. Anthropogenically, this landscape has been impacted by land use and land cover changes as a result of increasing socio-economic development, exerting substantial pressure on the existing forest areas. In the past decade, Social Forestry Schemes have been established under the Indonesian National Law (*PP. 23 Tahun 2021 tentang Penyelenggaraan Kehutanan Ps. 1*) that constitute ~8% of the total forest area in the region, offering protection to forests, natural resources, and communities.

Previous studies in this landscape (Cheyne *et al*. 2016, Mang 2022) have been localised focussing on specific areas, hence lacking landscape-level assessments of mammals. Our study is the first broad-scale, robust survey of terrestrial mammals across the Rungan-Kahayan landscape, aiming to establish baselines for mammal communities in fragmented forest blocks, particularly within community/locally managed forests. Our surveys aim to not only fill critical knowledge gaps on mammals in the region but also provide an opportunity to assess the role of community-managed forests in safeguarding vital and vulnerable mammal species in Kalimantan.

Material and Methods

Study area. We define our study landscape as lowland forest areas covering 4729.4 km^2 around the Rungan and Kahayan rivers. It is the region north of Palangka Raya city between the Rungan and Kahayan rivers in Central Kalimantan and stretches 100 km between them from east to west. It spans three administrative districts of the province, Kotamadya Palangka Raya, Kabupaten Gunung Mas, and Kabupaten Pulang Pisau. The landscape lies at a low altitude (ca. 10 - 60 m asl). Typically, the area experiences a tropical climate and is characterised by two major seasons, wet (April–October) and dry (November–March). Humidity levels in this region are high and can reach up to 95%. The mean annual rainfall is 2666 mm, and the mean temperature ranges from 20–35 ^{o}C.

We established nine sampling sites in forest blocks ranging from the south to the north of the landscape (Fig. 1). Of these, eight sites were in social forestry areas—seven in community forests (*hutan desa*) and one in a customary forested area (*hutan adat*). One site was in an area of forest designated for education and research purposes, managed by the Universitas Muhammadiyah Palangka Raya. The nine sites varied in size (5.44–49.78 km^2) and were selected to provide a good representation of the mosaic habitat structure observed and the longitudinal extent of the landscape. Throughout, we have intentionally omitted the names of villages and sites to protect the location of sensitive species.

Data collection. We deployed Bushnell Core^{TM} DS and Maginon WK 30 camera traps with passive infrared motion sensors in 101 locations across all of our study sites between 2022–2023. Trap deployment was conducted in three cycles: May–August 2022 (three sites), October 2022 – Jan 2023 (three sites), March–June 2023 (one site), and July–October 2023 (2 sites) (Sup. Table 1). Each camera trap was deployed for 90–135 days per location with an inter-trap spacing of 1.0–1.5 km. Since our focus was terrestrial mammals, un-baited cameras were installed on trees at a height of 30-45 cm above the ground in locations with suitable terrain features, animal trails, and signs.

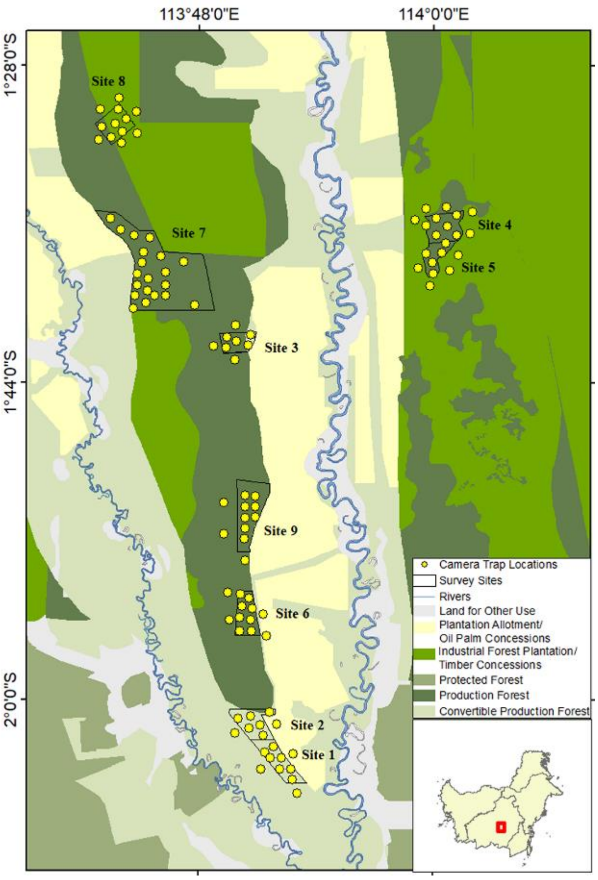

Figure 1. Map of the survey sites and camera trap locations in the Rungan-Kahayan Landscape.

Cameras were set to capture consecutive images per trigger with a delay of 0.1-0.6 seconds depending on the camera model. Cameras were set to provide continuous 24-hour monitoring throughout the deployment period.

Due to camera failures, malfunction, animal damage, and theft, we were able to retrieve data from only 86 locations. Photographs from retrieved cameras were examined after every deployment cycle for images of animals. Mammals were identified using Phillips & Phillips (2017) and Francis (2019), and sorted into species folders corresponding to each trap location at each site. Data were combined from all sites before analyses. Trapping effort (*i.e*. the number of functional camera nights; CTN) of each camera was calculated from the date when the camera was deployed until the camera was retrieved, or if the camera failed, until the date/time of the final exposure. Total trapping effort was defined as the sum of all camera trap nights of all cameras across sites.

We grouped mammals into categories based on; body size-Medium (1–5 kg, including small mammals) and Large (≥5 kg) (Haysom *et al*. 2021); threat status as Threatened (IUCN Red list categories from Critically Endangered to Vulnerable) and Non-threatened (IUCN Red List Categories Near Threatened and Least Concern); vertical stratification–Arboreal, Semi-arboreal (defined by species that spend a portion of their time in trees but are not exclusively tree-dwelling) and Terrestrial; and by their taxonomic group (Fig. 2).

Data analysis. <u>Conservation status</u>: We report the conservation status of each species based on the latest Red List assessment by the International Union for Conservation of Nature (IUCN). Throughout, species were assigned to one of five categories: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT) and Least Concern (LC) (IUCN 2024). We further assign CITES (Convention on International Trade in Endangered Species of Fauna and Flora) appendices I (species threatened with extinction and trade is only permitted in exceptional circumstances with permits), II (not necessarily threatened with extinction and trade is closely controlled allowing commercial trade) and III (protected species in at least one country and countries have the right to make unilateral changes in trade policy) (CITES 2020). In addition, we assign protection status under the National Protected Species List of Indonesia under the Regulation of the Ministry of Environment and Forestry of Indonesia ((NO. P.92/MENLHK/SETJEN/KUM. 1/8/2018) (MoEF 2018; Fig. 2, Sup. Table 2).

<u>Independent capture events (IE)</u>: To assume independence between individuals within photographic captures and reduce autocorrelation in the data, we assigned a 60-minute interval between each capture or if subsequent detections within this threshold contained different individuals or species (O'Brien *et al*. 2023). All data processing, including the calculation of independent events, was conducted in R using the camtrapR package (Niedballa *et al*. 2016). We calculated the following metrics using the derived CTN and IE from the camera trap data.

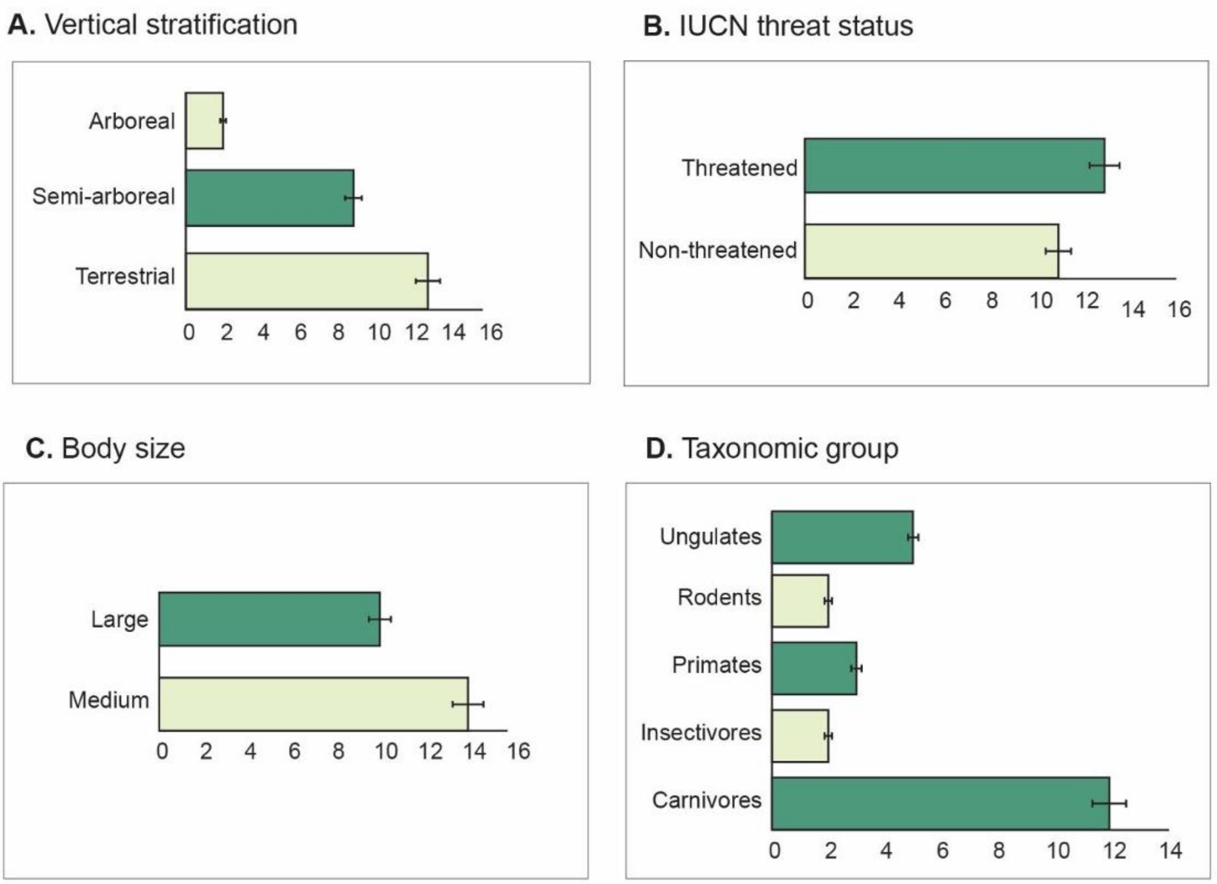

Figure 2. The number of species detected on terrestrial camera traps for **(A)** vertical stratification (arborealy/terrestrial); **(B)** IUCN threat status (threatened = categories form VU to CR; non-threatened = category LC); **(C)** body size (medium = >1, 5kg), and **(D)** taxonomic group.

Encounter rate: We calculated the encounter rate for each camera trapping site in our study area to allow for standardised comparisons between sites. The encounter rate was calculated as the percentage of the total number of IE detections from all camera locations in one site to the number CTN of all camera traps in that site. Encounter rate = $[\sum IE_{site} / \sum CTN_{site}] \times 100$.

Relative abundance Index (RAI): To create a standardised measure to compare species abundances across different sites and time periods and in relation to the camera trap effort which varies widely throughout our study, we calculated the relative abundance index by calculating the total number of IE of each species standardised by sampling effort (per 100-trap nights) (Carbone *et al*. 2001). RAI = $[\sum IE / \sum CTNs] \times 100$

Naïve occupancy: Naive occupancy was calculated as a preliminary assessment of species distribution, which provides insights into the broad-scale patterns of species occurrence within a study area. Naïve occupancy was calculated as the proportion of camera traps that recorded a particular species divided by the total active camera traps in the study area. The maximum occupancy value is 1, which indicates that a species occupies 100% of the sites surveyed (Rovero *et al*. 2014).

Naïve occupancy = No. (CT)s / $\sum$CT

Survey Effort: We calculated survey effort (number of trap nights to get a single photograph of the species) as the time required to detect mammals if they are present at the location (Jenks *et al*. 2011). Survey Effort = Total CTNs / $\sum$ IE

Species Accumulation curves: To quantify the optimal trapping effort (CTN) required to capture a good representation of mammals in the study area, we generated sample-based rarified and extrapolated (to double the survey effort) curves using iNEXT package in R (Chao *et al*. 2014). Sampling saturation was assumed to be met when the observed cumulative number of mammal species reached an approximate asymptote for the 90-130 days deployment period (Fig. 2).

Habitat associations: To infer the main habitats used by each species, we overlaid a habitat layer (Anirudh 2024). The habitat layer has nine categories. Of these, our camera locations were represented in seven distinct habitat types: secondary/disturbed; mixed-kerangas; flat-stunted kerangas; low-pole swamp (grouped category including very low-pole and low-pole swamp); clearing/forest gap; mixed-swamp/riverine, and; scrub/grassland. We plotted IE per habitat type for species with the top 10 highest RAI (excluding lesser mouse deer). To show potential habitat preferences using the ggplot2 R package (Wickham 2016).

Species distribution: For a subset of six protected species, we calculated the total number of IE for each of these species in each habitat type. We used this to create distribution maps to identify areas within each trapping site as low to high independent detections of species. The maps were created by superimposing a 2 km grid across the entire study area using the 'Fishnet' tool in ArcMap v10.8. We merged the camera locations with the grid using spatial join, where each camera location was assigned a value of independent captures of each of the six protected species chosen. Subsequently, we produced separate maps for each species indicating the location of detection and weighted by four categories of the number of independent captures of the species (1 being low and above 5 being high).

Results

From 86 camera traps and 2925 camera trap nights, we obtained 936 independent captures of 24 mammal species. Most mammal species detected were terrestrial mammals (*n*=13) and semi-terrestrial/arboreal (*n*=9) (Fig. 2). The richest order was Carnivora, with 12 species followed by even-toed ungulates (Artiodactyla) constituting five species (Fig. 2, Sup. Table 2). Civets (Viverridae) (*n*=4) and cats (Felidae) (*n*=3) were the most species-rich families of the Order Carnivora. Based on the IUCN Red List, 13 species detected in the landscape are considered threatened (Fig. 2). Two species, the Bornean orangutan (*Pongo pygmaues*) and the Sunda pangolin (*Manis javanica*) are listed as Critical Endangered, three species as Endangered - Bornean clouded leopard (*Neofelis diardi*), southern pig-tailed macaque (*Macaca nemestrina*) and the otter civet (*Cynogale bennetti*) of which we report the first capture in the study region. Of those species classified as threatened, only nine species are listed under the National Protected Species List of Indonesia. The remaining 11 species were classified as Least Concern under the IUCN categories, although four of these species are protected under the National Protected Species List (two species of mouse deer, *Tragulus kanchil* and *T. napu*; banded linsang, *Prionodon linsang*; leopard cat, *Prionailurus javanensis*). Three species in the community were also endemic to Borneo, namely, the Bornean yellow muntjac (*Muntiacus artherodes*), red langur (*Presbytis rubicunda*) and the Bornean orangutan (*Pongo pygmaeus*; Fig. 2, Sup. Table 2). We obtained an overall mammal encounter rate of 10.34%. The highest encounter rates tended to be at sites in the north of the landscape, and typically in drier forest types as compared to the wetter peat habitats in the south: Site 7 (18.9%), Site 8 (15.8%), and Site 9 (13.2%), whereas the rest of the sites had an encounter rate of <10%.

Relative abundance Index (RAI). Comparing, RAI across all species encountered, the sambar deer (*Rusa unicolor*) had the least relative abundance (0.01), while the lesser mouse deer was the most prevalent (6.04). Three species with the lowest RAI values were distributed across three separate orders, i.e. (Artiodactyla) sambar deer; (Carnivora) Bornean clouded leopard, and Small-toothed palm civet (RAI = 0.02). When species were partitioned according to body size, medium-sized mammals had a higher RAI (n = 14; RAI = 0.54 ± 1.53) compared to large mammals (n = 10; RAI = 0.27 ± 0.28). As expected, we found the RAI of threatened species to be considerably lower (n = 13, RAI = 0.23 ± 0.26) compared to most species that fall under the non-threatened category (n = 11; RAI = 0.67 ± 1.7). It is interesting to note that the majority of the species with the highest RAI were protected species such as the Malayan sun bear (RAI = 0.77); the southern pig-tailed macaque (RAI = 0.59), Bornean yellow muntjac (RAI = 0.57) and the Bornean orangutan (RAI = 0.43) under the National Protected Species List.

Naïve occupancy. Most species in our study were detected only once or twice in either one or two locations. Examples of these are the sambar deer, small-toothed palm civet (*Arctogalidia trivirgata*) (naïve occupancy = 0.01), and the three species of felids (naïve occupancy = 0.02) where we detected only one individual at one site. The lesser mouse deer (naïve occupancy = 0.57), Malayan sun bear (*Helarctos malayanus*) (naïve occupancy = 0.48), southern pig-tailed macaque (naïve occupancy = 0.34) and the two endemics, Bornean yellow muntjac and Bornean orangutan (naïve occupancy = 0.28) were captured on the greatest number of cameras and exhibited the highest RAI and Naïve occupancy (Sup. Table 2). When we compared Naïve occupancy values to a subset of data based on body size, there was not much difference between medium and large-sized mammals concerning the distribution of species within these categories (Naïve occupancy = 0.16 and 0.1 respectively). This was similar to the distribution of species in the subset of protected against (NT – CR) un-protected species (LC), where there was no substantial difference between the two groups (Naïve occupancy = 0.141 and 0.11 respectively). Based on the above two metrics, we conducted a Pearson's correlation between RAI and naïve occupancy for each species. We observed a strong linear correlation (99%; r=1.00, t=16724, p<0.001), where species with the highest RAI values and those with the highest naïve occupancy in the study area.

Survey effort. Generally, medium-sized mammals required less trapping effort to be captured compared to the larger mammals (1466.7 vs. 2070.3 CTNs respectively). The lesser mouse deer was the highest detected species across all our study sites and required little trap effort for detection (16.54 CTNs), while the most effort was required to detect the sambar deer (9050 CTNs). Although the Malayan sun bear was frequently detected across all our camera locations in every site, the effort required to capture the species was considerably higher than for the lesser mouse deer (129.28 CTNs). Despite differences in detectability amongst species, the observed asymptote in the species accumulation curve indicated that the mammal community was adequately sampled during the survey period (Fig. 3). This suggests that an approximately three-month period is an adequate sampling effort to develop a reliable species inventory.

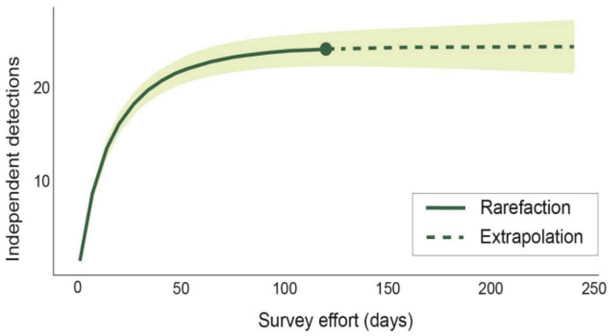

Figure 3. Rarefied and extrapolated species accumulation curve for mammals based on trapping effort (90–130 days) to the cumulative independent detections of species (*n*=24). The curves were based on Hill's number with q=0 (species richness) and were extrapolated (dashed line) to approximately double the minimum observed sample size. Confidence Intervals (shaded area) were set to 95%; the number of bootstraps was set to 100 (Chao *et al*. 2014).

Habitat uses. The low-pole swamp was the predominant habitat type across the study area comprising 38.2% of the area, followed by mixed-swamp/riverine forest (30.4%) (Sup. Table 3). Most camera traps were deployed in mixed-swamp/riverine habitat type (44.18%) followed by mixed-kerangas (22.1%). The highest capture rates, relative to the area covered by each habitat type were recorded in clearing/forest gaps (79.25) and mixed-kerangas habitat type (16.59). Despite these differences, the number of species detected in mixed-kerangas and mixed-swamp/riverine were the same (*n*=19).

Among the detected species, the Malayan sun bear was detected in all habitat types, although the species was detected most in mixed swamp/riverine habitat (*n*=30). The Bornean yellow muntjac, lesser mouse deer, and the southern pig-tailed macaque were also detected in all habitat types except in shrub/grassland habitat. The Bornean yellow muntjac was most frequently observed in mixed-kerangas (*n*=28), while the macaque and lesser mouse deer were more commonly detected in mixed-swamp/riverine (*n*=218 and *n*=24 respectively). Species belonging to the family Artiodactyla were predominantly detected in drier mixed-kerangas habitat compared to other habitat types, where encounter rates (2.40 IE/camera) exceeded those in mixed-swamp/riverine (1.27) and low-pole swamp (1.03). Despite low-pole swamp being the third most dominant habitat type, it yielded the second lowest encounter rate (0.20 IE/camera traps) after shrub/grasslands (0.13). The yellow-throated marten (*Martes flavigula*) and the short-tailed mongoose (*Herpestes brachyurus*) were the only two species that had a higher number of captures in low-pole swamp habitat as compared to other habitat types. There were only two species, the small-toothed palm civet and the sambar deer that were specific to one habitat type, i.e., mixed-swamp/riverine and shrub/grassland respectively. Comparing habitat use between threatened (IUCN: VU-CR) and non-threatened (LC) species, threatened species were captured predominantly in mixed-kerangas habitat, driven by the habitat preferences of the Bornean yellow muntjac, otter civet, and the southern pig-tailed macaque. Non-threatened species were detected more in the mixed-swamp/riverine habitat, particularly the lesser mouse deer and the moonrat (*Echinosorex gymnure*; Fig. 4).

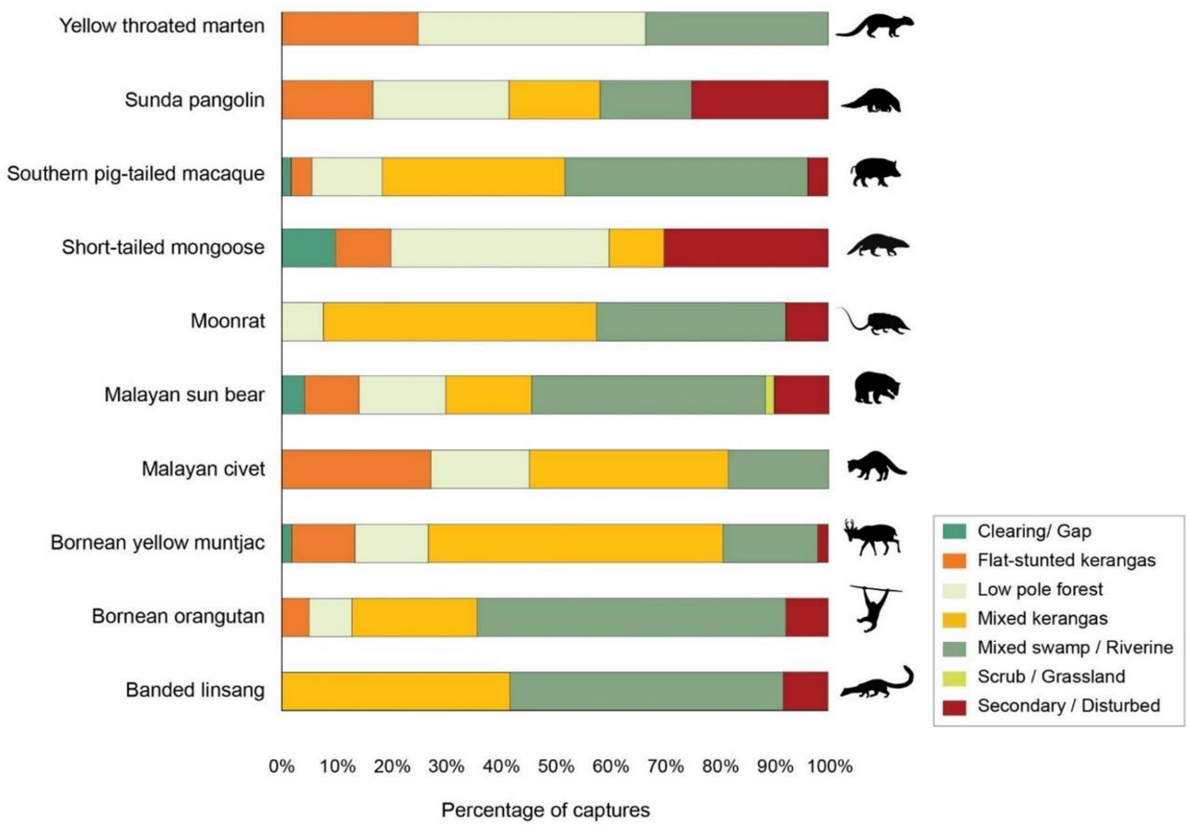

Figure 4. Stacked bar charts indicating percentage of detection of a subset of species with high RAI values in different habitat types

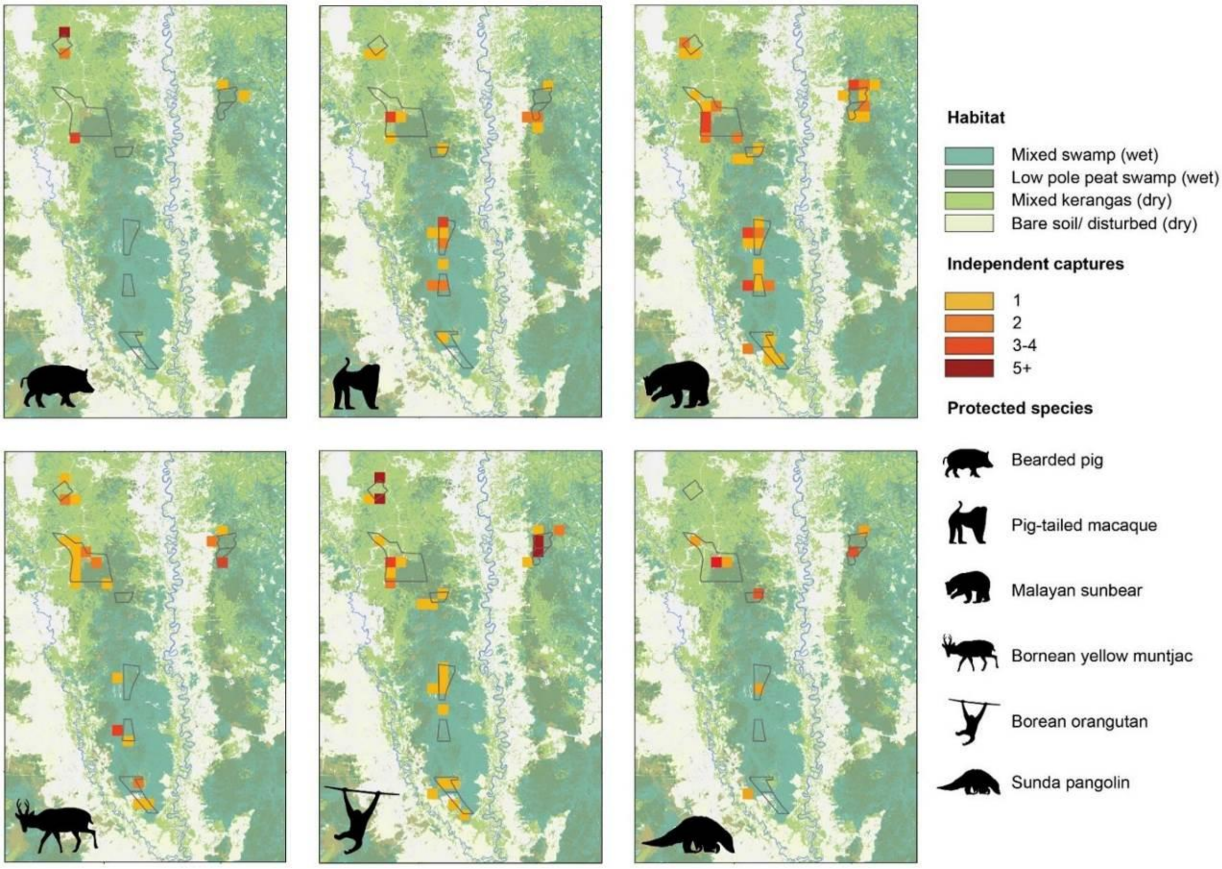

Figure 5. Species distribution maps for six protected species (listed as VU, NT, EN, CR) recorded in the Rungan-Kahayan landscape, Central Kalimantan, Indonesia

At the site level, site 8 had the highest rate of capture of mammal species, where 14 species were detected (Sup. Table 1). However, Site 7 had the highest number of species (*n*=19) and independent detections of mammals (357), despite the lower capture rate. Though recorded across all sites, the Malayan sun bear and the lesser mouse deer were detected the most in Site 7. Site 3 characterised by a mixed-swamp habitat and was smaller in area than the other sites in the study, showed a moderately high rate of detection (8.90) compared to the majority of other sites surveyed. Species of conservation significance, including the southern pig-tailed macaque, the Bornean yellow muntjac, and the Bornean orangutan, were found in eight of the nine sites (except in Site 9, Site 3, and Site 1 respectively). Sites 1 and 5 had the lowest number of detections and were among the sites with the least number of species detected (*n*=6, *n*=9 respectively; Fig. 5).

Discussion

Mammal inventories play a crucial role in both practical and theoretical applications. They are fundamental to ecological studies and conservation management (Kitamura *et al*. 2010). They allow basic interpretations of species richness and diversity (Loeb *et al*. 2001) and facilitate comparisons across different sites. Inventories also aid in mapping distributions, and provide fundamental information for more advanced analyses of mammal community dynamics (Tobler *et al*. 2008). The use of camera traps has become essential in wildlife studies (Silveria *et al*. 2003), Unlike traditional survey techniques, camera trapping is more effective at capturing rare and elusive species, offers standardised methods, and is less labour intensive (Moore *et al*. 2020). They also allow for remote monitoring of species in landscapes with difficult access and densely forested areas (Burton *et al*. 2015).

In this study, we used photographic capture rates as an index of relative abundance to demonstrate differences in mammal community composition relative to sites and habitat types. Although RAI does not account for biases arising from variable detection probabilities of species (Owens *et al*. 2024), or imperfect detection (Palmer *et al*. 2018) and is less reliable for smaller-sized and cryptic species (Sollmann *et al*.

2013), it provides valuable, albeit basic insights into community structure and dynamics of medium-to-large sized mammal communities when derived from systematic sampling. (Sollmann *et al*. 2013, Burton *et al*. 2015, Palmer *et al*. 2018). Another metric we used was Naïve occupancy, a straightforward measure of species presence across sites. While this metric underestimates the true occupancy of species (Mackenzie & Bailey 2005) and does not factor in detection probability (i.e., if a species is present at a site, it will always be detected, and if not detected the site is considered unoccupied, which may be a false absence) (Rayan & Linkie 2020), or habitat suitability (Lele *et al*. 2012), it can be used as a quick estimate of species distribution.

We obtained a relatively high diversity of medium to large-sized mammals in the Rungan-Kahayan landscape compared to other camera trap inventories from Borneo (Sup. Table 4). We report 24 species across seven orders and 14 families, including a newly recorded species, *Cynogale bennettii* (otter-civet), for this area of Central Kalimantan. We reached a high sampling saturation where species accumulation curves achieved an asymptote, providing confidence that our trapping effort adequately characterises mammals in the landscape. However, some notable species were not detected, including long-tailed macaque (*Macaca fascicularis*), flat-headed cat (*Prionailurus planiceps*), Bornean Bay cat (*Catopuma badia*), red muntjac (*Muntiacus muntjak*) and other species of civets and otters that are potentially found in this region. This could be due to several factors such as human-wildlife conflict, considering our survey areas border other land use types, facilitating human accessibility and presence in these areas; hunting of macaques (Tiempo *et al*. 2023); low detection rates (Mohd-Azlan *et al*. 2023); increased homogeneity of habitats due to neighbouring monocultures (Tee *et al*. 2019) and species-specific habitat preferences (Rovero *et al*. 2014).

Since non-detection does not necessarily confirm the true absence of a species from an area (Mohd-Azlan 2009), particularly where other studies have provided evidence of species presence, a more structured design based on habitat diversity and robust analyses such as multi-species occupancy models may yield a more accurate species inventory accounting for non-detection and estimation of true occurrence and distribution of species (Benoit *et al*. 2018).

Species-specific habitat preferences were evident in our findings for certain species, including both wet swamps and drier heath forests, where the mean capture rate across all species was more in drier areas (0.91) compared to swamps (0.29), despite swamp forests dominating our study areas. Although a better representation of habitats could potentially aid in detecting species that may be restricted or prefer specific habitat types (Bernard *et al*. 2013), we acknowledge this as an advantage, as swamp habitats, especially peat swamps are disproportionately under-sampled due to difficult accessibility and terrain (Posa & Marques 2012). Our study provides valuable insight into the inferred biodiversity value of peat habitats and provides the first assessment of fauna in the unique mosaic habitat of this landscape.

The Malayan sun bear, southern pig-tailed macaque, lesser mouse deer, Bornean yellow muntjac, and Bornean orangutan were the most frequently detected species, had the highest relative abundance indices, and demonstrated habitat plasticity. These findings are consistent with other studies elsewhere in the region (Cheyne *et al*. 2016, Bernard *et al*. 2013, Mohd-Azland *et al*. 2018). However, while most published inventories report the bearded pig as the most commonly occurring species, we only captured seven independent detections of this species across three sites (Sites 4, 7, and 8) in the Rungan-Kahayan landscape. Two of the three sites have evidence of bearded pigs from previous wildlife surveys (Site 7 - Cheyne *et al*. 2016; Site 8 -Mang 2023), which suggests that the extirpation of bearded pigs happened recently. Pigs are a commonly hunted species (Love *et al*. 2018, Kurz *et al*. 2023) as is sambar deer – another seemingly rare species in the landscape, suggesting that human pressure may be responsible for the low detection rates. Hunting effects may be exacerbated by African Swine Fever, which has spread rapidly across wild pig populations in Borneo since being detected in Sabah in 2021 and is associated with extremely high mortality rates (Khoo *et al*. 2021, Luskin *et al*. 2023).

Carnivores were the order most commonly recorded in our study constituting five families and 12 species which is consistent with previous studies in Borneo (Bernard *et al*. 2013, Moh-Azlan *et al*. 2018, Leo *et al*. 2024). Of special mention is the elusive, endangered otter-civet, which has very low detection (n=4) in our study and was recorded only at Site 5. Interestingly, it was only found in the low-pole swamp habitat type, which constituted 38.2% of the total forest cover across our landscape, though 17% of our cameras were in this habitat type. Low-pole swamps are unique and rare habitat types. They often occur on domes of peat swamp forests and in lower wetter regions of kerangas forests and share similar physiognomy to both these habitat types. These characteristics make this habitat type suitable for wetland specialists, such as the otter civet (Veron *et al*. 2006). Amongst published records of this species, there is evidence of its distribution with low detection rates in lowlands, peat swamps, and mangroves in West and East Kalimantan, Sumatra, and parts of Malaysian Borneo (Heydon & Gaffar 1997, Veron *et al*. 2006, Bernard *et al*. 2022, Leo *et al*. 2024). To our knowledge, this study confirms a new locality for the otter-civet in Central Kalimantan, complementing other published records of this species in Sebangau National Park, Tanjung Puting National Park, and Bukit Batikap Protected Forest (Cheyne *et al*. 2016) and further highlights the importance of peat dominated forests and swamps in harbouring unique specialist species.

Amongst the felids, the Bornean leopard cat, Bornean clouded leopard, and marbled cat were detected in our surveys, albeit at low capture rates, consistent with other studies (Mohd-Azlan *et al*. 2023, Evans *et al*. 2016). Research suggests that leopard cats are commonly detected in disturbed areas, particularly in and around oil palm plantations (Mohd-Azlan & Sharma 2006, Jennings *et al*. 2015). Although we obtained a very low capture rate of leopard cats, likely due to our camera locations predominantly in forest interiors, the species was detected exclusively at sites bordering oil palm plantations (Sites 1, 9, and 3). Most captures of felids were from cameras that were deployed in mixed- and short-stunted kerangas, further emphasising their preference for drier habitats (Matsuda *et al*. 2010). These findings highlight the significance of tropical heath forests, which are often dismissed as ‘wastelands’ or ‘depauperate’ forests (Bittencourt *et al*. 2022), despite providing critical niches for species with specific ecological requirements.

Some of the least detected medium-sized mammals across our study sites belonged to the family Viverridae, though they represented the family with the greatest number of species captured in our study. We attribute low detections to several reasons that were not accounted for in our study such as species-specific behavioural traits and ecological niches - spatial habitat partitioning (e.g. vertical stratification in small-toothed palm civet). For example, the low detections of the linsang and Malay weasel could be attributed to the inter-camera distances in our trapping design, and their preference for dense understorey (Duckworth *et al*. 2006, Jennings & Veron 2015), while the small-toothed palm civet is typically arboreal (Veron *et al*. 2015, Evans *et al*. 2016). It is important to recognise that viverrids occupy varied niches in ecology and hence contribute to several ecological functions (Moresco & Larsen 2014). Hence their low encounter rates may signal compromised ecosystem functioning, given evidence that densities of small carnivores, particularly civets are likely to be high in undisturbed forests (Mudappa 2014).

Ungulates (Order: Arctodactyla) were abundant across our study site, although the relative abundance is weighted heavily on the two mouse deer species and the Bornean yellow muntjac. However, the highest RAI for five species of ungulates recorded were in drier areas or drier habitat types in the landscape, i.e. clearing/forest gap (RAI = 2.68), and kerangas habitat (2.29). In other records of ungulates, it has been shown that they are commonly found in secondary-growth forests or in areas with dense undergrowth, that provide foraging opportunities due to the high availability of browse (Brodie & Giordano 2013). These habitat characteristics were consistent with those seen in kerangas and in forest gaps, where an increased incidence of light onto the forest floor due to relatively open canopies allows a greater abundance of saplings, seedlings (Nafiah *et al*. 2022), shrubs, and grasses, the dietary requirements for ungulates.

In summary, mammal communities include species with diverse habitat preferences as evidenced by our findings. Accordingly, heterogeneous mosaic habitats are likely to support a great number of species and are fundamental to protecting biodiversity. It is important to note that all the sites in this study are managed by local communities under the social forestry scheme and/or for education purposes, in other words, lack strict long-term protection. In addition, the mosaic structure of the landscape with several land use types and habitats that are overlooked in conservation planning (e.g. the oligotrophic - low nutrient, low-productivity heath forests, and low-pole swamp habitats) (Struebig *et al*. 2006), and increasing pressures from socio-economic development in the area, add a layer of future uncertainty onto the sensitive state of mammals in these fragmented forests. Despite these increasing threats in the region, we demonstrate a rich inventory of mammal species including several rare, endemic, and endangered species within these locally managed forest blocks. Hence, it warrants urgent attention to mitigate human pressures and implement effective conservation strategies in the remaining forest blocks within the Rungan-Kahayan landscape.

Here, we provide the first large-scale species inventory of local community and institutionally managed forest blocks in the Rungan-Kahayan landscape in Central Kalimantan. We documented sensitive and cryptic species in a previously un-surveyed area without a strict protection status. To prevent losses and mitigate risks of species decline, it is crucial to set baselines and understand the alpha and beta diversity of wildlife, in an area that is typically fragmented and faces increasing anthropogenic pressures The non-detection of several species of conservation importance requires further investigation to understand possible localised extinctions and their causes. This data is essential for understanding basic mammal ecology in tropical rainforests and in facilitating effective management of locally managed forest blocks. Regular monitoring of wildlife in these areas is critical for assessing threats and conservation needs, ensuring the long-term viability of species, especially those of conservation importance.

Author contributions

All authors played a significant role in designing, conducting the research, and writing the manuscript. Data compilation and identification: NBA, EE, RH; Data analysis: NBA, RH; Writing: NBA; Review and edits: MJS, NJD, JS.

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