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Small carnivore diversity in forest patches around oil palm plantation in West Sumatra, Indonesia

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Abstract. *Solina ID, Mukhtar E, Novarion W, Dahelmi. 2023. Small carnivore diversity in forest patches around oil palm plantation in West Sumatra, Indonesia. Biodiversitas 24: 1824-1832.* The accelerating rates of forest conversion into agricultural land are the main driver for biodiversity loss. How biodiversity, particularly secondary consumers, can adapt to different agricultural schemes is critical to conservation planning. Currently, small forests within oil palm plantations should receive more attention, especially as they are habitats for small carnivores, and it is still unknown how they respond to habitat change. We analyzed camera trap data from 2015 to 2018 in key High Conservation Value (HCV) forests in South Solok, West Sumatra: Kencana Sawit Indonesia company (forest patch A) and Tidar Kerinci Agung company (forest patches B and C). LecoS is used to collect landscape metrics data then evaluated using the Generalized Linear Models (GLM) to assess the impact of fragmentation on the presence of small carnivores in forest patches. The model with the lowest Akaike Information Criterion (AIC) value was the one we regarded to be the most acceptable. We found 12 species of small carnivores belonging to 4 families; six species were identified in patch A, ten in patch B, and only three in patch C. We identified that land covers are the most important parameter on the presence of small carnivores in oil palm plantations in West Sumatra based on GLM results. Due to the importance of forested regions to small carnivore diversity, we recommend increasing forest connectivity into and across oil palm landscapes.

Keywords: Agricultural land, camera trap, fragmented forest, GLM, HCV, LecoS, mesopredator

INTRODUCTION

Intensification of agricultural land use is a key contributor to the loss of biodiversity and the decline of important ecosystem services. Across Sumatra, it continues to pose a significant risk to rich biological diversity (Fitzherbert et al. 2008). The production of oil palm is very significant to Indonesia's economy (Dirjenbun 2016). However, the clearing of land to establish palm oil plantations often results in the destruction of forests, which exacerbates biodiversity loss, pollution of watersheds, and climate change (Fitzherbert et al. 2008; Meijaard et al. 2020). The destruction of forests, particularly for the purpose of expanding oil palm plantations, has already been shown to have had negative effects on a large number of forest mammals (Kwatrina et al. 2018; Solina et al. 2018). The impacts of deforestation and land use conversion on Sumatra's carnivores, in particular, have been less studied relative to other species (McCarthy and Fuller 2014; Haidir et al. 2021; Sibarani et al. 2022). Because of their comparatively large size of carnivorans relative to other mammals, and their trophic position among ecosystems, carnivorans may be more vulnerable to habitat degradation (Lyra-Jorge et al. 2008). Understanding the impact of these processes, therefore, is extremely important, as many species of carnivores are threatened and have a positive impact on biodiversity (Cazzolla Gatti et al. 2019; Meijaard et al. 2020).

Relative to larger carnivores, which have received significantly more research and conservation attention, the impact of these anthropogenic processes on smaller carnivores has received comparably less (Holden 2006; Chutipong et al. 2014; Jennings et al. 2015; Torres-Romero and Giordano 2022). A more thorough understanding of their regional distribution, feeding ecology, and habitat preferences, to name a few important aspects of their biology, would yield information critical to planning for their conservation. We already know, for example, that many fruit-eating species play an important function as seed disperser agents in tropical forests. In addition, although Southeast Asia hosts the greatest diversity of small carnivores in the world (Torres-Romero and Giordano 2022), some to many of these species have little or no tolerance for anthropogenic changes to forest landscapes; they are therefore unable to live in ecosystems that have been profoundly altered by humans. Even though other studies have reported on the diversity of carnivores that can "use" oil palm concessions, the ecological and conservation effects of oil palm plantations on small carnivores are still not well recognized (Jenks et al. 2011; McCarthy and Fuller 2014; Semiadi et al. 2016; Sibarani et al. 2022), as we know little about their ability to persist in these land use contexts over time.

A significant reduction in forest area and canopy cover has been shown to have a substantial effect on the presence of mammals, particularly carnivores. Carnivorous mammals need relatively larger home ranges relative to other mammals to meet their foraging and resource utilization needs, as well as cover and reproductive requirements. Forest fragmentation, and the relegation of more expansive forests to riparian or gallery forest patches, limit the availability of food for many carnivores, thereby increasing home range area, energetic requirements, movement activity, and a greater likelihood of competitive interactions or anthropogenic mortality. The long-term effects of forest fragmentation can cause the disappearances of local carnivore populations (i.e., local extinctions), ultimately resulting in ecological imbalances in those wildlife communities that remain (Pusparini et al. 2014; Sunarto et al. 2015; Weiskopf et al. 2019). Consequently, more efforts to better identify how and which fragmented forests can protect small carnivores is important to top-down decision-making regarding landscape management and conservation. This is particularly true for small carnivores using and persisting in oil palm landscapes, which this study aimed to learn more about.

MATERIALS AND METHODS

Study area

We conducted our study in three West Sumatran lowland tropical forest regions that are considered to have high conservation value (HCV) forests, such as two limited companies, *Perseroan Terbatas* (PT), as the owner of the oil palm plantation. Two of these patches are within PT. Tidar Kerinci Agung (TKA) territory and the third is in the PT. Kencana Sawit Indonesia oil palm farms (KSI) (Figure 1). The PT. TKA plantations are located in the regencies of Dharmasraya, South Solok in the West Sumatra province, and Bungo (Jambi Province), ranging roughly from 101º26"-101º40" E to 01º25"-01º40" S, with an altitude between 250-700 m asl, and fall under climatic zone A due to the significant amount of rainfall they receive each year. Two HCV Forest sections, patch C (1292 ha) and patch B (1648 ha), which are close to Kerinci Seblat National Park (KSNP), constitute the 5099 ha of conservation forests in the PT. TKA area (KSNP). All of the forest patches were chosen due to the status were HCV or conservation areas as each company needs to preserve. Human activities, including logging, clearing land for plantations, and other disturbances, have had an impact on the forest region in PT. TKA, changing the native vegetation. PT. KSI, an oil palm plantation with a total size of 10,216 ha, is nearby PT. TKA. It is classified as a secondary forest and covers 1271 ha in a conservation forest region, with patch A comprising 709 ha. The PT. KSI region is located in the same geographic area as PT. TKA and is classified as climate zone A.

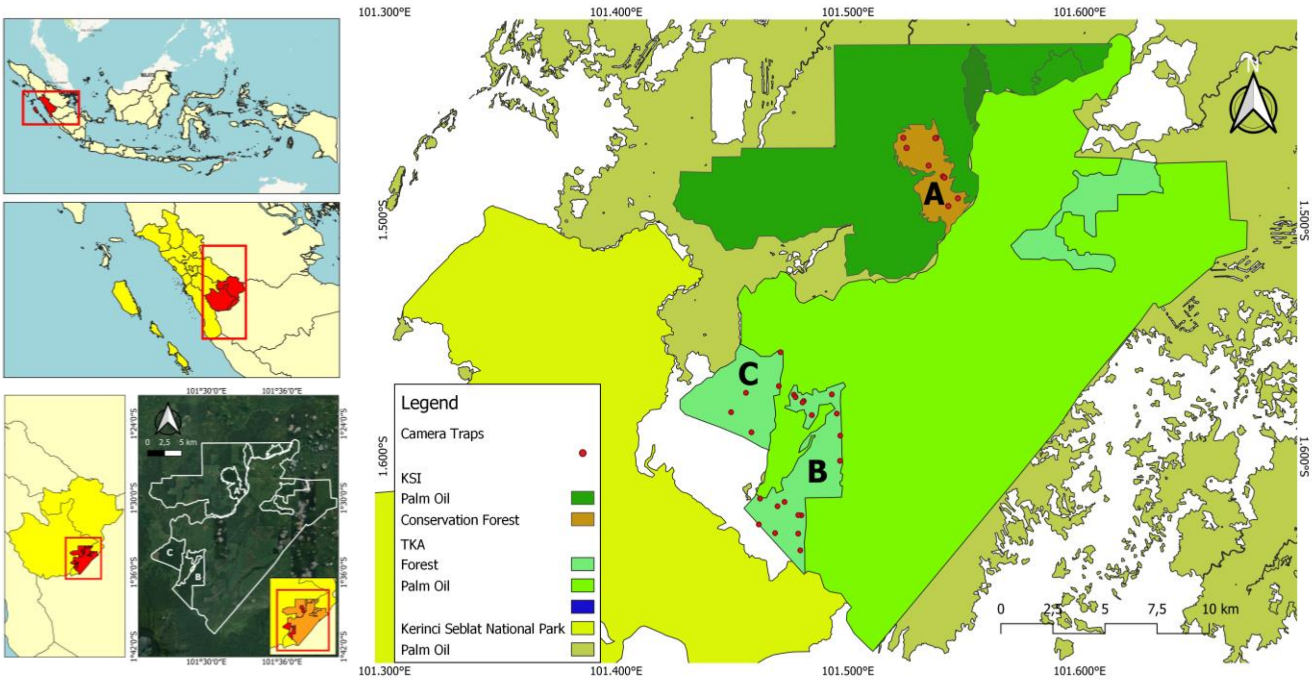


Figure 1. A map of the study area in Solok Selatan District, West Sumatra, Indonesia. Forest patch A is a fragmented forest inside PT. KSI oil palm plantation. Forest patches B and C are located inside PT. TKA oil palm plantation, Patch C is bordered by Kerinci Seblat National Park Forest

Material and methods

Camera-trapping survey

We recorded video of wildlife from camera traps installed between 2015 to 2018 (multi-seasonal) across our study area (Figure 1). The camera traps were used for wildlife monitoring in both oil palm companies. In this study, we only used small carnivores' presence data and the other animal were excluded. The forest patches chosen were HCV forests as it was categorized by Indonesian Sustainable Palm Oil (ISPO), which means these companies were certified by ISPO. Eight camera-trap stations were deployed in one forest patch (A) in the PT. KSI area and about 1.08 km average spacing distance. In the PT. TKA conservation forest areas, 19 camera-trap stations were deployed in a forest patch (B) directly near TNKS (Kerinci Seblat National Park), with a 0.96 km average spacing distance and six camera-trap stations were placed in another forest patch (C) with 1.46 km average spacing distance. Purposive sampling was used to set camera traps in each location grid (1x1 km) of the forest area. Cameras were established at the height of 40-50 cm above the ground and fixed to a tree along a trail, path, or similar area where wildlife can be expected to move. Cameras were checked every month, and the coordinates and altitude of each camera were recorded. Total camera-trap nights are the number of nights a camera operated (from deployment to retrieval) X the total number of camera traps. The total number of camera-trap nights for our entire study was 2246, 4824 and 771 for Patches A, B, and C, respectively.

Species diversity and relative abundance

All mammals captured by camera traps were identified to species level. Photos of the same species were treated as independent occurrences at the same camera trap if they occurred >30-minute intervals apart. Counts of independent photographs for each species were used to calculate several measurements of species richness and diversity, such as; Shannon-Wiener diversity indices (H'), species richness index (Margalef diversity index and Menhinick diversity index (Magurran 2004), and relative abundance of small carnivores, which is relative “activity”, as RAI = (A/N) × 100, where A is the total number of detections of a species by all cameras, and N is the total number of camera-trap nights or days for all the cameras throughout the study area (Jenks et al. 2011).

We created rarefaction curves using iNEXT (Interpolation and Extrapolation) online program by (Chao et al. 2014) at https://chao.shinyapps.io/iNEXTOnline/ to compare the species composition in the three forest patches. We calculated the total species richness (including observed and undetected species) in each of the three areas of the forest using the vegan library's poolaccum function. Chao's, Jackknife, and bootstrap methods were used to calculate the estimations. While Jackknife and Bootstrapping tend to overestimate species richness if there are a lot of unusual species or insufficient samples, Chao's method is useful when many individuals are only captured a few times (Weiskopf et al. 2019).

Habitat and landscape metrics

Landscape data, including land cover, landscape percentage, edge length and edge density, and patch cohesion index, were obtained using the LecoS plugin (Jung 2016) in QGIS 3.16.3. Here, landscape metrics are used to assess the degree of disturbance. Land cover refers to the different types of things that can be found on the Earth's surface, such as forests, grasslands, and water bodies (Nedd et al. 2021). The proportional ratio of each sort of patch in the landscape is measured by landscape proportion (Narmada et al. 2021). Edge length is the total distance separating two distinct land cover types or patches (Kleinn et al. 2011). Edge density is the ratio of edge length to land area, which is a class-level landscape metric. Edge length and edge density indicate how fragmented an area is, the higher the edge length and edge density values, the more fragmented the area (Ma et al. 2012). We used LecoS to characterize how fragmented and open the forest patch area is.

We then used Landsat 8, the data were acquired in the year 2020, to calculate the Normalized Difference Vegetation Index (NDVI) (retrieved from earthexplorer.usgs.gov), i.e., NDVI = (Band 5 – Band 4) / (Band 5 + Band 4). In NDVI, bands 5 and 4 are used to compare how much red and near-infrared light is reflected by vegetation. Band 4 monitors the quantity of red light, while Band 5 specifically measures the amount of near-infrared light. It is employed to evaluate the vitality and health of vegetation. Higher values indicate denser and healthier vegetation, while lower values indicate less vegetation or stressed vegetation. The NDVI values typically range from -1 to 1, with negative values denoting non-vegetated areas (such as water or bare land), values close to zero denoting sparse or stressed vegetation, and values close to 1 denoting dense and healthy vegetation. NDVI is also a predictor for models trying to understand the forces that shape the distribution of small carnivores (Pettorelli et al. 2011).

Furthermore, the Generalized Linear Model (GLM) test uses these data as predictors. We used a generalized linear model (GLM) with a stepwise backward function in R statistic to analyze the relationships between small carnivore abundance and various landscape metrics, including edge length, NDVI, altitude (alt), landscape proportion (lprop), and land cover (lcov) as covariates. We examined relative evidence support among possible models and compared Akaike Information Criterion (AIC) values (Burnham and Anderson 2002).

RESULTS AND DISCUSSION

Species diversity and relative abundance

We recorded 12 small carnivore species from four different families across all three forest patches (Table 1). Six species of three families and comprising a total of 36 independent photos were discovered in patch A, the forest fragment farthest from Kerinci and thus potential source habitat. Ten species of small carnivores from four families and comprising 70 independent photos were identified from patch B, the patch closest to Kerinci, whereas only three species of small carnivores from one family were identified in patch C.

We recorded the most trap nights for forest patch B (4824) and the fewest for patch C (771). For patch A, we logged 2246 trap nights. The species distribution in each forest patch differed (Figure 2) because some species were only found in one or two patches, but none were found in all three patches. Patch B had the largest Margalef and Menhinick diversity indices, whereas patch C had the smallest. *Arctictis binturong, Martes flavigula, Paradoxurus hermaphroditus,* and *Prionailurus bengalensis* were the four species common to patches A and B (Figure 3). *Arctogalidia trivirgata* and *Paguma larvata* were only found in patches B and C. *Neofelis diardi, Catopuma temminckii, Pardofelis marmorata,* and *P. bengalensis* all occurred in patch B, whereas the only other forest patch where a felid species was present (only *P. bengalensis*) was patch A. Because of variations in camera trap efforts, the number of species detected in each forest area may vary (Figure 4).

Table 1. Small carnivore species, independent photos from each forest patch, IUCN Red List status; Least Concern (LC), Near Threatened (NT), Vulnerable (VU). Area: forest patch (Figure 1), Relative Abundance Index (RAI)

Taxa	Common name	Area			RAI			IUCN Status
		A	B	C	A	B	C	
Order: Carnivora								
Felidae								
Catopuma temminckii	Asian golden cat	0	12	0	0	0.249	0	NT
Neofelis diardi	Clouded leopard	0	7	0	0	0.145	0	VU
Pardofelis marmorata	Marbled cat	0	3	0	0	0.062	0	NT
Prionailurus bengalensis	Leopard cat	7	21	0	0.312	0.435	0	LC
Mustelidae								
Martes flavigula	Yellow-throated marten	3	1	0	0.134	0.021	0	LC
Viverridae								
Arctictis binturong	Binturong	1	1	0	0.045	0.021	0	VU
Arctogalidia trivirgata	Small-toothed palm civet	0	1	1	0	0.021	0.13	LC
Hemigalus derbyanus	Banded palm civet	7	0	0	0.312	0	0	NT
Paguma larvata	Masked palm civet	0	2	1	0	0.041	0.13	LC
Paradoxurus hermaphroditus	Common palm civet	14	19	0	0.623	0.394	0	LC
Viverra tangalunga	Malayan civet	4	0	0	0.178	0	0	LC
Prionodontidae								
Prionodon linsang	Linsang	0	4	1	0	0.083	0	LC
Total IE		36	70	3				
Trap night		2246	4824	771				
H'		1.554	1.80	1.090				
Margalef Index		1.395	1.883	1.820				
Menhinick Index		1.000	1.076	1.732				

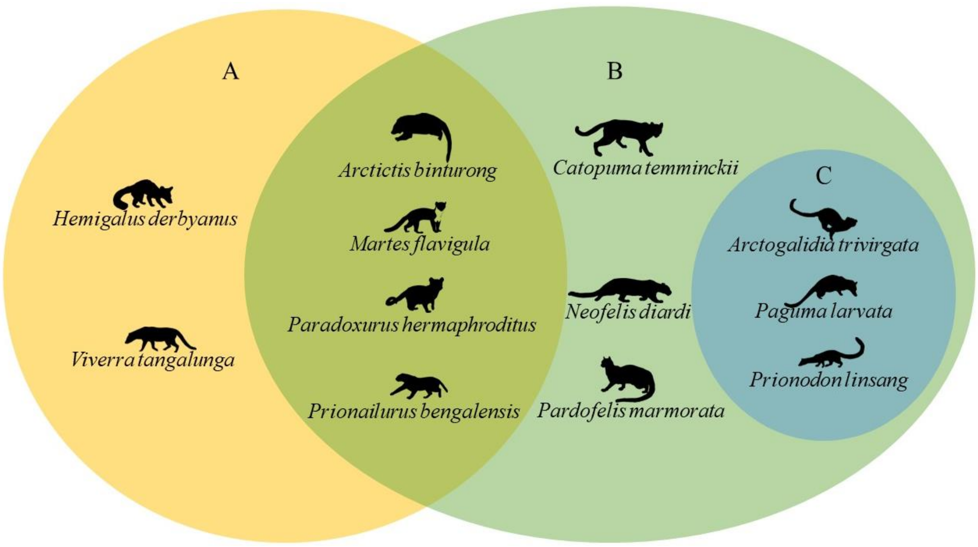


Figure 2. A comparison of the small carnivore composition of the forest patches A, B, and C in oil palm landscape in West Sumatra

A B

Figure 3. Small mammal documentation. *Prionailurus bengalensis* (A) and *Martes flavigula* (B) found at locations A and B

Paradoxurus hermaphroditus had the highest RAI value among all species found (0.623 in patch A), whereas *A. binturong* had the lowest value (0.021 in patch B). The IUCN conservation status of seven of the species we recorded was considered Least Concern (LC); however, five are considered declining and/or threatened species. Three species have Near Threatened (NT) status, and two have Vulnerable status. Most species of the family Viverridae were considered LC except for *H. derbyanus* (NT), whereas *A. binturong* has VU status. A comparison of the small carnivores found in each of the forest patches is shown in Figure 2, whereas examples of photographs from our camera trap surveys are depicted in Figure 3.

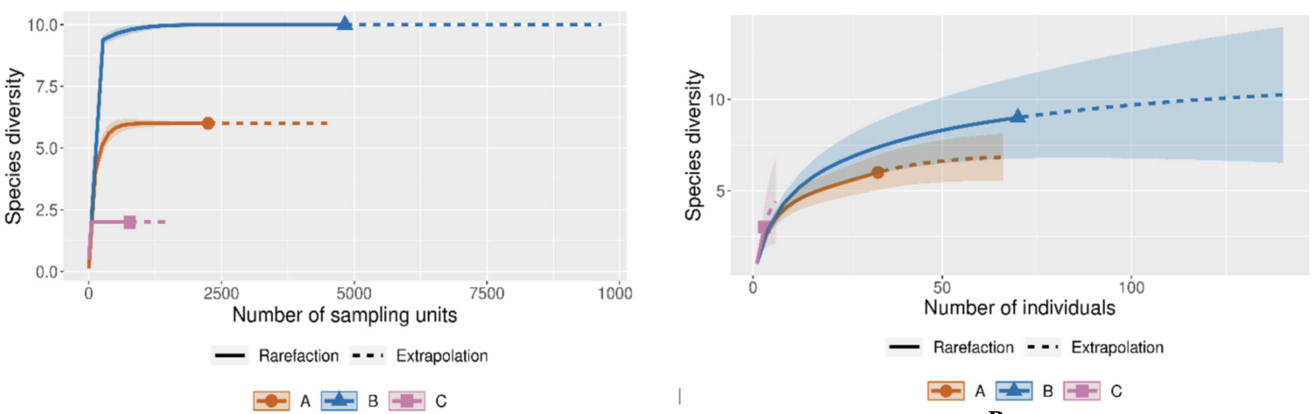
Habitat and landscape metrics

According to the landscape and habitat characteristics we examined, each forest patch had a different size. Patch A naturally had the lowest area due to the land cover forest, whereas Patch B had the greatest (Table 2). Despite the fact that forest patch C is larger than forest patch A in terms of area, they are both fragmented forests according to the values of edge length and edge density (Table 3).

We examined the importance of land cover (lcov), landscape proportion (lprop), NDVI, altitude (alt), and edge length as a proxy for patch fragmentation value, to small carnivore presence among oil palm plantations. The RAI land cover model has the smallest AIC value (Table 4), indicating that land cover is the primary influence on the relative abundance of small carnivores in the plantation landscape. We also found that a diverse altitudinal range can positively influence the presence of certain species, especially; *C. temminckii*, *P. marmorata*, and *P. linsang*.

Table 2. Landscape metrics data for each forest patches

Landscape metrics	Forest patches		
	A	B	C
Land cover	4.53km²	16.37km²	12.36km²
Landscape proportion	2.27×10^{-7} km²	9.84×10^{-7} km²	5.06×10^{-7} km²
Edge length	0.09 km²	0.05 km²	0.11 km²
Edge density	1.07×10^{-8} m/ha	2.87×10^{-9} m/ha	8.06×10^{-9} m/ha



A B

Figure 4. Rarefaction based on number of individuals (A) and sampling units (trap nights) (B) and extrapolation (dotted line segments) curves for species richness with 95% confidence intervals (shaded area) for three forest patches

Table 3. Estimated small carnivore species richness in the three forest patches near Kerinci Seblat National Park. The observed species richness is referred to as "species." The species richness estimators "Chao," "Jackknife," and "Bootstrap" take into consideration species that the camera traps missed

Estimate type	Patch A		Patch B		Patch C	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
Species	6	-	9	-	3	-
Chao	6.87	1.98	11.13	3.23	5.4	3.46
Jackknife	7.75	1.81	11.84	1.64	5.4	1.87
Bootstrap	6.74	1.05	10.44	1.07	3.98	0.99

Table 4. GLM modelling result

Model covariate	Estimate	SE	z value	*P* value	K	AIC	ΔAICc	Weights
RAI model								
RAI~lcov+lprop+ndvi+edge_length+alt					7	-461.98	223.30	0
(Intercept)	3.25E-02	1.06E-01	0.308	0.7583				
Land_cover	-1.25E-08	6.66E-09	-1.871	0.0623 •				
land_proportion	1.39E-01	9.17E-02	1.512	0.1316				
ndvi	8.58E-02	1.42E-01	0.605	0.5455				
edge_length	-4.23E-06	1.51E-05	-0.281	0.7789				
alt	4.32E-05	1.85E-04	0.234	0.8152				
RAI~lcov+lprop+ndvi+ edge_length					6	-464.02	221.27	0
(Intercept)	5.28E-02	5.99E-02	0.883	0.378				
Land_cover	-1.17E-08	5.88E-09	-1.994	0.047 *				
land_proportion	1.38E-01	9.15E-02	1.506	0.133				
ndvi	6.78E-02	1.19E-01	0.57	0.569				
edge_length	-1.12E-06	7.01E-06	-0.159	0.874				
RAI~lcov+lprop+ndvi					5	-466.07	219.21	0
(Intercept)	4.76E-02	4.98E-02	0.955	0.3405				
Land_cover	-1.17E-08	5.87E-09	-1.995	0.0469 *				
land_proportion	1.36E-01	9.06E-02	1.501	0.1344				
ndvi	7.91E-02	9.51E-02	0.832	0.406				
RAI~lcov+lprop					4	-467.44	217.85	0
(Intercept)	8.65E-02	1.71E-02	5.067	6.96e-07 ***				
Land_cover	-1.19E-08	5.87E-09	-2.032	0.043 *				
land_proportion	1.35E-01	9.05E-02	1.486	0.138				
RAI~lcov					3	-685.29	0	1
(Intercept)	7.58E-02	1.35E-02	5.606	3.9e-08 ***				
Land_cover	-3.82E-09	1.00E-09	-3.819	0.0002 ***				
Model Interaction								
species*alt					24	230.68	0	0.9
(Intercept)	2.02E-01	2.71E+00	0.075	0.9406				
Arctogalidia trivirgata	-8.38E-01	4.60E+00	-0.182	0.8555				
Catopuma temminckii	-1.39E+01	7.33E+00	-1.904	0.0570 •				
Hemigalus derbyanus	1.32E+01	8.98E+00	1.464	0.1431				
Martes flavigula	-6.51E-01	3.41E+00	-0.191	0.8486				
Neofelis diardi	-7.93E+00	6.04E+00	-1.313	0.1893				
Paguma larvata	-3.62E+00	3.73E+00	-0.972	0.3311				
Paradoxurus hermaphroditus	3.29E+00	3.25E+00	1.012	0.3116				
Pardofelis marmorata	-1.27E+01	3.24E+00	0.507	0.1214				
Prionailurus bengalensis	1.64E+00	4.96E+00	-1.577	0.6125				
Prionodon linsang	-7.82E+00	5.72E+00	1.166	0.1148				
Viverra tangalunga	6.67E+00	5.83E-03	-1.004	0.2435				
alt	-5.85E-03	9.94E-03	0.021	0.3155				
Arctogalidia trivirgata: alt	2.04E-04	1.03E-02	2.157	0.9836				
Catopuma temminckii: alt	2.22E-02	2.44E-02	-1.319	0.0310 *				
Hemigalus derbyanus: alt	-3.22E-02	7.08E-03	0.333	0.1872				
Martes flavigula: alt	2.36E-03	9.18E-03	1.334	0.7391				
Neofelis diardi: alt	1.23E-02	7.09E-03	0.987	0.1822				
Paguma larvata: alt	7.00E-03	6.88E-03	-0.407	0.3237				
Paradoxurus hermaphroditus: alt	-2.80E-03	1.11E-02	1.74	0.6841				
Pardofelis marmorata: alt	1.94E-02	6.89E-03	-0.096	0.0819•				
Prionailurus bengalensis: alt	-6.58E-04	7.97E-03	1.648	0.9238				
Prionodon linsang: alt	1.31E-02	1.48E-02	-1.058	0.0994•				
Viverra tangalunga: alt	-1.57E-02	3.24E+00	0.507	0.2901				

Note: lcov: land cover; lprop: landscape proportion; ndvi: Normalized Difference Vegetation Index; alt: altitude. Significant codes: 0 '***'; 0.001 '**'; 0.01 '*'; 0.05 '•'; 0.1 ' ' 1

Discussion

In this study, we discovered a variety of small carnivores living in forest patches among oil palms near KSNP. Similar to previous research, we found fewer species in the fragment forests (Patches A and C) than in the continuous forest (patch C) (Lyra-Jorge et al. 2008; Bernard et al. 2014; Weiskopf et al. 2019). Even though patch C had camera traps for a longer period of time than other patches did, it hasn't reached the asymptote in the rarefaction curve (Figure 4). The majority of small carnivore research has previously been done in conservation forests (Pusparini et al. 2014; McCarthy et al. 2015; Ladyfandela et al. 2018). A previous study recorded around 16 small carnivores that occurred in National parks in Sumatra based on a camera trap survey (Sibarani et al. 2022). Total number of small carnivores species recorded to this date in Kerinci Seblat National Park was 19 species belonging to three families (Mustelidae, Viverridae, and Felidae) (Holden 2006). Hence, this study contains information on around 63% of the small carnivore found in KSNP.

Among the three forest patches in the oil palm landscape, forest patch A has the smallest area but can still accommodate six species, which accounts for 50% of the total species found in this oil palm plantation's landscape. One species, *H. derbyanus*, with Near Threatened (NT) status, was found only in patch A, which did not exist in larger patches B and C. Moreover, *V. tangalunga* was only found in patch A. The largest small carnivore species found in patch A is *A. binturong*. This suggests that patch A is important for a variety of small carnivores. Smaller habitat patches typically support fewer species than larger ones because various species have differing habitat size requirements, and they usually contain only a subset of the species found in larger patches (Fahrig 2003).

Forest patch B, which is the largest forest area in this study, is directly connected to KSNP. In this patch, ten species of small carnivores from four families were discovered, each with unique characteristics. The member of the Felidae family found in this patch have a body size ranging from 2 kg (*P. bengalensis*) to 25 kg (*N. diardi*). Although other large carnivores, such as Sumatran tigers and bears, were also found, they were excluded from the study’s analysis. Since felids are hypercarnivores (Sunquist and Sunquist 2002) and require a significant amount of habitat for foraging to find prey (Machado et al. 2017), this may be the reason why felids, except for *P. bengalensis*, were not found in patch A, the smallest forest patch.

Despite having a larger area than patch A, only three species were recorded in forest patch C. This is probably due to lower camera trap effort than in other patches. As the rarefaction curve shows that it didn’t reach the asymptote yet, it means there is more chance of discovering more species, if the effort is increased. The results of the study indicate that the diversity of small carnivores in Patch C is now quite low. This still holds even closer to natural woods like KSNP. Despite being adjacent to KSNP, Patch C lacks a connecting forest that would provide a corridor for access because it is fragmented. *Arctictis binturong*, also known as the bearcat, is distributed throughout South and Southeast Asia, including Kalimantan, Sumatra, and western Java. Although considered an arboreal species, camera trap photos show it engaging in ground activity (Willcox et al. 2016), possibly explaining its rarity in this study. The ideal habitat for Binturong is lowland forests, with recorded home ranges of 6.2 km^2 for males and 6.9 km^2 for females (Chutipong et al. 2014). The species' specific needs remain undefined, but it is evident that plantations, burnt forests, and open areas are unsuitable for their survival based on habitat modeling in Borneo (Semiadi et al. 2016).

Martes flavigula is extensively dispersed in South, Southeast, and East Asia with notable populations in Kalimantan, Sumatra, and most of Java in Indonesia (Chutipong et al. 2016), as well as 57% confirmed populations in Thailand, protected evergreen forest (Chutipong et al. 2014). This species can be found in a wide range of environments; however, it cannot be found in oil palm plantations or lowland or highland forests with old growth and active logging (Hon et al. 2016). *Martes flavigula* has a 7.2 km^2 home range, thus it needs a large habitat to thrive. However, because it consumes a variety of foods, it can adapt to varied situations (Chutipong et al. 2016).

Prionailurus bengalensis is a very adaptable species that may be found all over Sumatra, Kalimantan, and Java in natural forests, rivers, peat swamps, plantations, and residential areas (Silmi et al. 2013; Pusparini et al. 2014; Jennings et al. 2015; Sunarto et al. 2015; Mohamed et al. 2016). As a generalist, it can adapt to different environments (Cheyne et al. 2016). In Bukit Barisan National Park, *P. bengalensis* model showed that precipitation, altitude, and distance from the forest's edge were critical factors (Mccarthy et al. 2015). *Catopuma temminckii* is a woodland cat species found in Bangladesh, Bhutan, Cambodia, India, Indonesia (Sumatra), Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Thailand, and Viet Nam (McCarthy and Fuller 2014; Pusparini et al. 2014; Sunarto et al. 2015). The species is primarily found in forest habitats, and studies conducted at Bukit Barisan Selatan National Park revealed that the species' occurrence was influenced by the distance to the forest edge, river, and road (McCarthy et al. 2015). While *C. temminckii* prefers medium elevation in Kerinci Seblat National Park, it is more abundant in montane and lower montane forests in Gunung Leuser National Park (Mccarthy et al. 2015; Haidir et al. 2021).

Pardofelis marmorata is a native species from Bangladesh, Bhutan, Brunei Darussalam, Cambodia, India, Lao PDR, Malaysia (Peninsular Malaysia, Sabah, Sarawak), Myanmar, Nepal, Thailand, Vietnam and Indonesia (Kalimantan, Sumatra). This species is found in Sumatra from Aceh to the southern section of the island (McCarthy and Fuller 2014; Pusparini et al. 2014; Sunarto et al. 2015; Ladyfandela et al. 2018; Solina et al. 2018; Haidir et al. 2020; Widodo et al. 2022). Species of *P. marmorata* are known to be less vulnerable to changes in forest cover (McCarthy et al. 2015), preferring deep forest environments far from human disturbances (Struebig et al. 2015; Haidir et al. 2021). *Pardofelis marmorata* inhabits medium-elevation hills and lower montane-to-montane habitats (Pusparini et al. 2014).

Borneo, Brunei Darussalam, Malaysia (Peninsular Malaysia, Sabah), Burma, Thailand, and Indonesia are the native habitats of the *Prionodon linsang* species (Java, Kalimantan, Sumatra). Primary forests, secondary forests, and regions in which humans reside are all potential habitats for this species (Duckworth et al. 2016). This species can be found even in the scattered forests of the Bukit Barisan Selatan National Park area (Weiskopf et al. 2019).

Borneo and Sumatra are home to the indigenous species *N. diardi*. Due to the lack of distribution data for *N. diardi* in Sumatra compared to Borneo, this species' distribution in Sumatra is only concentrated in National Park regions (Hearn et al. 2016). Considering that *N. diardi* may be found in a variety of forest habitat types, altitudes, and disturbance levels, it is a relatively adaptable species (Brodie et al. 2014; Pusparini et al. 2014; Brodie et al. 2015; Haidir et al. 2018). However, while being quite adaptable, *N. diardi* has never been discovered using oil palm plantations (Maddox et al. 2007; Jennings et al. 2015).

The GLM findings suggest that land cover should be considered a crucial factor in promoting the conservation of small carnivores in oil palm plantations. Additionally, the positive impact of the altitudinal range on the presence of certain species highlights the importance of preserving and protecting diverse landscapes to support wildlife diversity. Fragmented forests will alter the composition of small carnivore communities. Moreover, a fragmented forest will isolate wildlife and may result in local extinction (Fahrig 2003). Connecting fragmented forests to larger forests requires the construction of forest corridors (Rosenberg et al. 1997). Riparian forests that connect small patches within the oil palm landscape can serve as natural connectors, thus riparian forests also need to be conserved. These results could have important implications for conservation efforts aimed at mitigating the impact of oil palm plantations on wildlife populations and communities.

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