Activity pattern and habitat profile of small carnivores in an oil palm landscape

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Abstract

As of 2010, approximately 55,000km^2, or 12% of Sumatra island, was subject to oil palm cultivation. This has resulted in the mass clearing of tropical forests, which has led to many isolated forest fragments, as well as the disruption of ecosystem functionality. While the impact of these activities on larger carnivores has been well-established, how they have impacted the ecology of smaller carnivores, including mustelids and viverrids, has been much less studied. Between June and December 2015, we conducted camera-trap surveys to investigate the activity patterns and habitat characteristics of small carnivores in Solok Selatan near Kerinci Seblat National Park, a region containing extensive oil palm plantations. We established a total of 15 camera-trap stations, including five cameras in each of three different habitats: fragmented forest, riparian zones and continuous forest. A statistical analysis was carried out using Generalized Linear Model (GLM) to assess the relationship between species richness among various habitat and covariates, then compared with Akaike Information Criterion (AIC) values to identify the most likely models were run in R statistic program. In general, the camera traps recorded seven species of small carnivore during monitoring, consists of one mustelid species exhibiting predominantly diurnal activity, and six viverrids that were largely active at night. Larger distances from the park edge were also associated with greater species richness at camera-traps, most likely because these species had become isolated in forest surrounded by completely unsuitable habitat. We conclude that this mixed oil palm landscape has negatively impacted small carnivore diversity and activity.

Pada tahun 2010, sekitar 55.292 km2 luasan perkebunan kelapa sawit mencapai 12% dari total pulau Sumatera itu sendiri. Pembukaan hutan menjadi perkebunan menimbulkan permasalah tersendiri, terutama timbulnya hutan terfragmentasi yang tidak terhubung dengan hutan sehamparan dan tidak berfungsinya riparian sebagai koridor penghubung. Dampaknya terhadap mamalia karnivora besar telah banyak diteliti, sementara untuk mamalia karnivora kecil belum diteliti, dengan demikian perlu dilakukan penelitian untuk mengetahui bagaimana pola aktivitas dari Mustelidae dan Viverridae di kawasan perkebunan kelapa sawit dan profil habitat yang mereka manfaatkan. Penelitian ini menggunakan metoda Camera trap. Sebanyak 15 camera dipasang pada tiga habitat; fragmentasi, riparian dan hutan sehamparan di dalam kawasan perkebunan kelapa sawit Solok Selatan, masing-masing habitat dipasangi 5 camera. Kamera dipasang dari bulan Juni-Desember 2015. Uji statistik menggunakan Generelized Linear Model (GLM) pada R statistic dilakukan untuk mengetahui hubungan antara keragaman spesies yang diperoleh dengan beberapa parameter lingkungan, kemudian diambil nilai Akaike Information Criterion (AIC) paling kecil dan sederhana untuk digunakan sebagai permodelan. Didapatkan total 7 spesies, satu Mustelidae yang memiliki aktivitas diurnal, dan 6 species Viverridae yang memiliki aktivitas nocturnal. Profil habitat dari kedua famili mamalia karnivora kecil ini menunjukkan bahwa tutupan kanopi dan jaraknya ke hutan Taman Nasional Kerinci Seblat mempengaruhi jumlah spesies yang ditemukan di kawasan perkebunan kelapa sawit tersebut.

Keywords: Mustelidae, Viverridae, activity patterns, habitat, forest fragmentation, oil palm, Carnivora, tropical forest

Introduction

Oil palm plantation is one of the most rapidly expanding commodity crops (Phalan et al., 2013)in Indonesia, with oil palm plantations mainly located on Sumatra and Kalimantan. Large monoculture plantations now dominate nearly 10-12% of Sumatra's 443,065.8 km^2 and more plantation development is expected in the near future (Rianto et al. 2012; Gunarso et al. 2013). Although oil palm plantation operations attempt to maximize the area they utilize, some areas are retained as

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forest due to the presence of challenging terrain or land contours, infertile soil, or the occurrence of riparian, wetland, and/or conservation areas. Whereas the protection of high conservation value areas is positive, the practice frequently leads to increasing habitat fragmentation, ultimately resulting in species decline (Mudappa et al., 2007; Fitzherbert et al., 2008; Syamsi, 2011; Bernard et al., 2014; Yue et al., 2015).

All species respond to forest fragmentation differently. Despite being able to fly, many bird species perceive roads, monoculture and open areas as barriers to their movement and dispersal (Farina, 1998). Many mammals in Southeast Asia are heavily dependent on intact tropical forests, include many predators, such as the Sunda clouded leopard (*Neofelis diardi*) and marbled cat (*Pardofelis marmorata*) (Pusparini et al., 2014; Duckworth et al., 2014; Bernard et al., 2014; McCarthy et al., 2014; Hearn et al., 2016; Rustam et al., 2016). One exception appears to be the leopard cat (*Prionailurus bengalensis*) that is common even in oil palm plantations (Rajaratnam et al., 2007; Silmi et al., 2013; Bernard et al., 2014; Jennings et al., 2015; Yue et al., 2015).

Riparian forests could potentially serve as corridors between larger forest tracts in an otherwise fragmented landscapes. Many species, including felids and other small carnivores, can make use of original standing vegetation along watercourses thereby contribute to species persistence across larger landscapes (Karsai and Kampis, 2011). To what degree corridors are important to smaller mammalian carnivores in tropical Asian landscapes, however, has not been tested yet.

The activity patterns of small carnivores are determined by the distribution and/or behaviour of their food resources, as well as the presence of potential competitors and predators (Sunarto et al., 2014). For carnivores in tropical landscapes like Sumatra, many species may occur sympatrically across large regions and thus occupy the same areas or even habitat (McCarthy et al., 2014a, b). To facilitate coexistence and avoid direct competition, sympatric small felid species occupying potentially similar niches may be active at different times on Sumatra (Sunarto et al., 2014). Although this is probably also true for viverrids and mustelids, comparisons of activity patterns among these species have received less attention than felids and other mammals.

This study aims at assessing the importance of forest fragments in an oil-palm dominated landscape to small carnivores, as well as what role if natural riparian corridors and forest fragments play, if any, in their persistence. We also aimed at improving our understanding of species coexistence and competition in altered landscapes, as well as the importance of various forest microhabitat characteristics on carnivore species richness.

Methods

Study Area

We conducted this study in Solok Selatan (3346.20 km^2), a district of West Sumatra Province, Indonesia, which comprise 60% of Kerinci Seblat National Park (KSNP). Our study area included two of ten palm oil plantation operations in the region: Tidar Kerinci Agung company (TKA), and Kencana Sawit Indonesia Company (KSI). These two areas comprised a total area of 86,093 ha (Government District: Solok Selatan, 2014). Our study areas consisted of three habitat types within the oil palm concessions: continuous forest bordering the KSNP, riparian forest inside the oil palm concession area and fragmented forest with mixed forest habitat (Fig. 1). The elevation of the TKA (101'26"-101'40" E and 01'25"-01'40"S) varies between 250-700 above sea level, with most of the TKA's total area (28.029 ha) dominated by secondary forest. All fragmented forest, hilly secondary forest, occurred in the conservation area of KSI.

Camera trapping

We deployed 15 Xenon-flash digital camera-traps (DTC-565) to conduct our surveys between June and December, 2015. Camera-traps were distributed evenly across each of the three habitat blocks: five

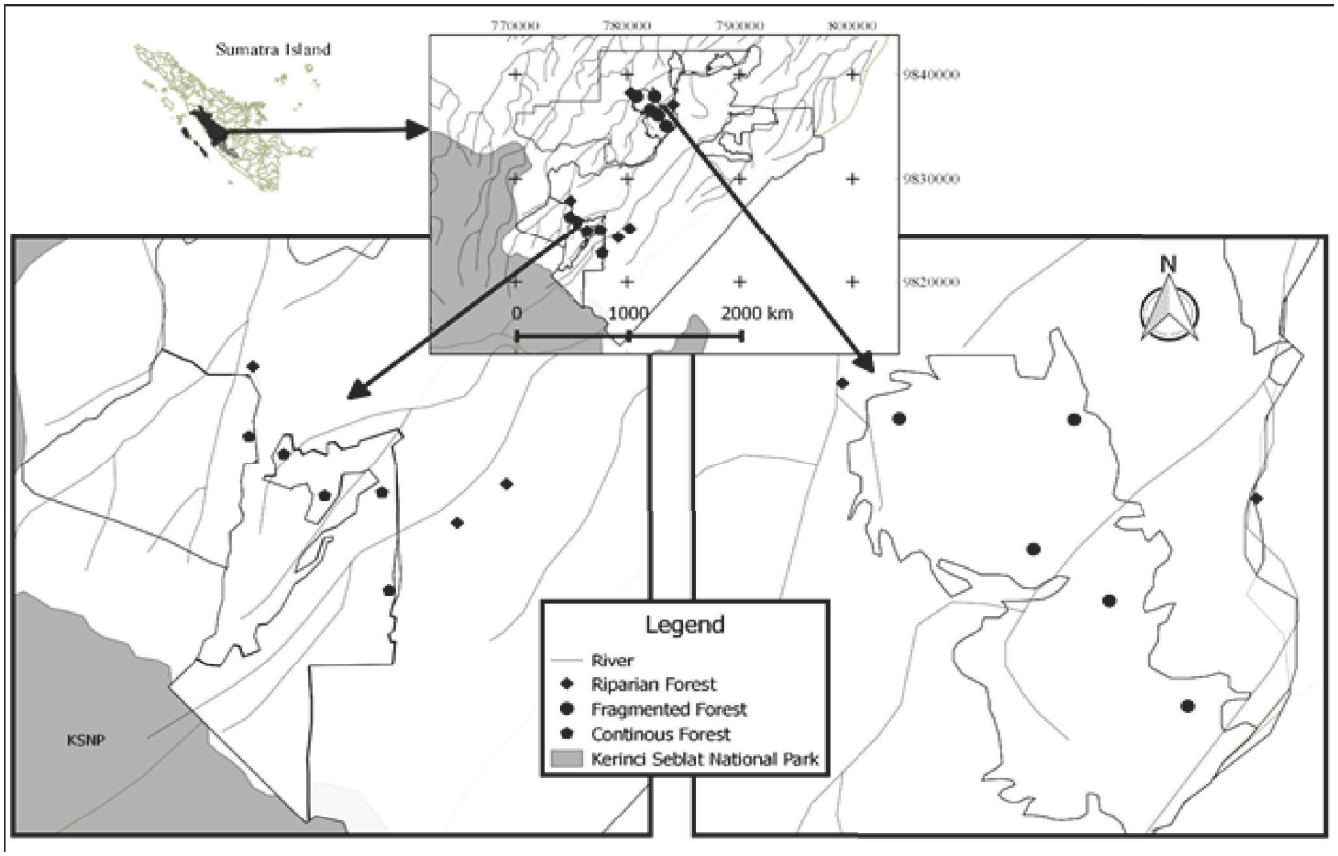

Figure 1. The study sites in a oil palm plantation landscape in Solok Selatan, West Sumatra, Indonesia, and the positions of the camera-traps. Left is continuous forest bordering the Kerinci Seblat National Park, and right is fragmented forest.

camera-traps were deployed in continuous forest adjacent to TNKS, five camera-traps were placed in riparian forest; and five camera-traps were put in the isolated forest fragment (KSI). To maximize spatiotemporal independence, no two camera-traps were <1 km apart. Camera-traps were affixed to tree trunks approximately 50 cm above the ground; trigger sensitivity was set to 'medium' and to take a single photograph at a time. All camera-traps operated 24-hours/day without the use of bait or lures and were each equipped with 2-4GB memory cards capable of storing more than 15,000 images per card. Cameras were checked monthly to change the batteries and memory cards. For ambiguous and unclear photos, we identified species using regional mammal field guides (Payne et al., 2000; Nowak and Paradisso, 1983) and through consultation with taxonomic experts (e.g, IUCN Small Carnivore Specialist Group).

Organization and preliminary analysis of photo data was assisted with software developed by Sanderson and Harris (2013). Lower values of interspecific comparison of activity suggest greater similarity between those patterns. To assess the relationship between species richness and various

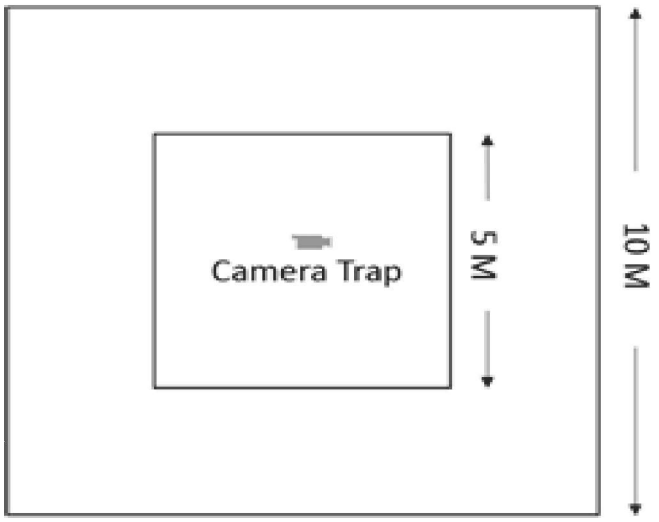

Figure 2. Vegetation analysis plots.

habitat characteristics and covariates, including relative sapling and tree density, canopy cover, distance to roads, distance to the KSNP forest, and distance to the nearest river, we used a Generalized Linear Model (GLM) with a stepwise backward function in R --- that is, variables with the highest Z values were reduced one by one until the most parsimonius models were identified. We then compared Akaike Information Criterion (AIC) values (sic. Anderson et al., 1998; Anderson and Burnham 1999) and contrasted relative evidence support among potential models.

Habitat characteristics

To characterize important habitat features surrounding camera-trap locations, we used a squared plot method (Fitri, 2012). Each camera-trap location constituted a central point encompassed by one 10x10m area plot to estimate tree number/ density, and one 5x5m area sub-plots for counting saplings (Fig. 2). We estimated canopy cover using a densiometer consisting of a 24 x 4 grid of total points in 10 x 10 m quadrant (Fig. 2) at 1 m above ground level in the center of the plot vegetation survey. This was done with the observer facing the camera-trap and counting the number of dots, allowing us to calculate the percentage of closed/ open canopy cover in areas immediately adjacent to camera-traps.

Results and Discussion

A total of 2,879 trap nights yielded 2,880 pictures of 23 mammal species. Of these, seven species (30.4%) were Mustelidae for which we obtained only 35 independent photos (Tab.1). Common palm civets (*Paradoxurus hermaphroditus*) were photographed most frequently (n=20, or 57% of all independent photo records of small carnivores) and were the only species detected in all three habitat types or more than one habitat. Surprisingly, we recorded more species (n=5) in the isolated forest fragmented, including the Binturong (Vu) (*Arctictis binturong*) and the Banded palm civet (NT) (*Hemigalus derbyanus*) not detected in other habitats. The small-toothed palm civet (*Arctogalidia trivirgata*) and the common palm civet were the only two species recorded in the riparian forest within the oil palm concessions.

Activity patterns

Of the seven small carnivore species we detected, only the yellow-throated marten (*Martes flavigula*) was recorded during the day (n=1; 09:00-10:00am); all six viverrids were recorded from around dusk through dawn (Fig. 3). Although we only recorded one photo of the yellow-throated marten, this species is known to be predominantly

Table 1. The species, English name and local name, number of independent photos, habitat and IUCN status for the small carnivores detected in the study site. Habitat - 'F' fragmentation, 'CF' - Continous Forest,' R - 'riparian'. IUCN status - 'VU' - vulnerable', 'LC' - least concern, 'NT' - near threatened.

Species	Common name	Local name	#Photos	%	Location	IUCN
Mustelidae						
Martes flavigula	Yellow-throated marten	Musang leher kuning	1	2.86	F	LC
Viverridae						
Arctogalidia trivirgata	Small-toothed palm civet	Musang Akar	1	2.86	R	LC
Arctictis binturong	Bearcat/Binturong	Binturong	1	2.86	F	VU
Hemigalus derbyanus	Banded palm civet	Musang Belang	7	20	F	NT
Paguma larvata	Masked palm civet	Musang Galing	1	2.86	CF	LC
Paradoxurus hermaphroditus	Common palm civet	Musang Luwak	20	57.14	F,CF,R	LC
Viverra tangalunga	Malay civet	Musang Tenggalong	4	11.43	F	LC
		Total	**35**	**100**		

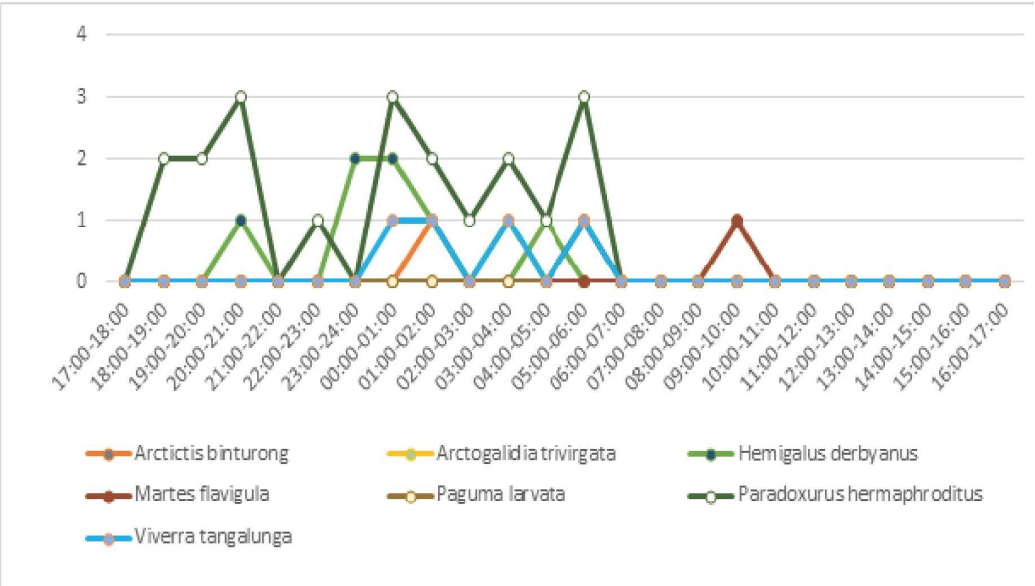

Figure 3. Comparative activity pattern of small carnivores in three forest types in western Sumatra.

diurnal, sometimes hunting at night during a full moon or shortly before sunrise (Grassman et al., 2005; Abramov et al., 2008; Cheyne et al., 2010; Mathai et al., 2010; Mccarthy and Fuller, 2014). Common palm civets (n=20) were active from dusk to dawn, with activity from 00:00 to 01:00am, 05:00-6:00am, and 20:00-21:00pm; conversely, lower activity rates were recorded between 02:00-03:00am, 04:00-5:00am and 22:00-23:00pm. We did not record common palm civet between 07:00am and 17:00pm and although it has adopted diurnal habits elsewhere (Cheyne et al., 2010), it is widely regarded as crepuscular and nocturnal (Azlan, 2003; Wilting et al., 2010). The banded palm civet appeared to be active between 19:00pm – 05:00am (n=7), whereas Malay civet occurred between 23:00pm – 05:00am. The Malay civet and Banded palm civet are known to be predominantly nocturnal and crepuscular (Azlan et al., 2008; Wilting et al., 2010; Brodie and Gioradano, 2011; Ross et al., 2015). Unfortunately, we only detected three of the six viverrid species once, including the binturong, small-toothed palm civet, and masked palm civet (Tab. 1). This prevented a better understanding of their diurnal activities at our study site. The ecology of Binturong is poorly understood and may vary between areas, as publications about diurnal activity and dispersal are conflicting (Wildmann et al., 2008). Grassman et al. (2005) noted the Binturong to be crepuscular and nocturnal, whereas Nettelbeck (1997) reports them as diurnal. Small-toothed palm civet is strongly nocturnal (Duckworth et al., 2008) and Masked palm civet is nocturnal with occasional diurnal activity (Duckworth et al., 2008b).

Despite our relative lack of detections, the activity of both Malay and common palm civets was comparable (Fig. 3). Direct competition between the two species may be reduced due to differences in the diet and behaviour. For example, the common palm civet is broadly omnivorous; it hunts rodents and other small vertebrates, insects and mollusks and also consume fruit in large quantities (Duckworth et al., 2008b). In contrast, the Malay civet is more terrestrial than the palm civet (Azlan et al., 2011; Eng, 2011), as well as relatively less frugivorous (Azlan et al., 2008). Although our data from this landscape is limited, it is possible that common palm civets are routinely active earlier in the day than Malay civets (Brodie and Giordano, 2011). Similarly, limited data on banded palm civets (n=7) suggest their activity is similar to common palm civets; both species were detected between 20:00pm and 01:00am (Fig.3). Banded palm civets are known to be more terrestrial than

Table 2. Quantitative measures of habitat features characterizing the three forest types in the study area.

	Sapling		Trees			Distance		
Forest	**Density**	**R. Density**	**Density**	**R. Density**	**Canopy**	**River(m)**	**KSNP(m)**	**Road(m)**
Fragmented	0.26	0.20	0.02	0.20	0.82	748.99	12405.6	284.49
Continuous	0.47	0.21	0.03	0.14	0.86	401.19	5252.68	199.41
Riparian	0.30	0.19	0.04	0.26	0.85	57.24	9454.63	19.00

Table 3. Results of a non-parametric Kruskall-Wallis test comparing microhabitat features of continuous forest, forest fragment and riparian forest.

	Sapling		Trees		
	Density	**R. Density**	**Density**	**R. Density**	**Canopy Cover**
X2	5.341	.383	1.426	1.673	.287
Df	2	2	2	2	2
Asymp. Sig.	.069ns	.826ns	.490ns	.433ns	.867ns

Table 4. Results of the GLM evaluating forest microhabitat features on the number of species detected

	Std. Error	**z value**	**P value**
(Intercept)	8.81	-2.615	0.00891 **
R. Density sapling	8.95	1.884	0.05955 .
Canopy Cover	7.29	2.579	0.00992 **
Distance to KSNP	0.0128	3.014	0.00258 **
AIC: 39.707			

palm civets, and consume smaller prey than Malay civets. A study based on stomach content analysis of banded civets on Borneo found no plant or fruit content of any kind, only insect parts (Hon et al., 2008).

Unfortunately, our data are not sufficient to evaluate and compare niche overlap for the small carnivore species detected in this study. Jennings and Veron (2011) recorded differences in habitat and elevation for the southeast Asian small carnivore community. They noted that, while niches might appear similar, they could be differentiated by how much each species utilized similar and very different habitat types, including tropical evergreen forest, deciduous forest, degraded forest, thick brush, plantation and marsh. More data from our site is needed to perform a rigorous analysis, however, it may not convey a meaningful picture, since the ongoing landuse change may impact the small carnivore populations in the area.

Habitat assessment

Sapling density was very similar for all three forest types (Tab. 2). Similarly, there was little variation in tree density or canopy cover between the study sites and there was no significant difference among habitats with respect to quantitative microhabitat features associated with camera-trap locations (Tab. 3). We tested the relationship between the number of species recorded and several micro and macro habitat variables, including relative density of saplings and trees; canopy cover; elevation; distance from the road; distance to natural forest (i.e., the KSNP) and distance to the river. The results of our generalized linear models (Tab. 4) yielded significant positive z scores for the canopy cover and distance to KSNP, suggesting that more closed canopy forest and greater distance from the KSNP were both associated with higher numbers of species detected at a camera-trap site. Results for the other covariates were not significant.

All of the photos that Wilting et al. (2010) recorded of banded palm civets occurred in forest with dense canopy cover. Another study reported

that binturong were predominantly active during the day under dense canopy cover (Grassman et al., 2005). Eng (2011) concluded canopy cover was an important microhabitat variable for Malay and common palm civets. The proportion of total records consisting of common palm civets supports the suggestion that this species is more at home in fragmented landscapes than its conspecifics. Both species probably impacted the relatively large and significant positive z-score for the number of species recorded at each camera-trap, which indicated increased distance from the KSNP edge was important. This could be due to the impacts of forest edge effects and fragmentation. Although fragmentation leads to the isolation of plant and animal species (Mitchell et al., 2015), it may also benefit a select number of small carnivore species. There is evidence that common palm civets can persist in human-modified habitats, including plantations and logged forest. Similarly, Malay civets have also been recorded frequently in degraded and modified habitats although not as much as common palm civets (Jenning and Veron, 2011; Jenning et al., 2015; Wilting et al., 2010; Mathai et al., 2010). Mudappa et al. (2007) concluded that small carnivores (Mustelidae, Viverridae) in India were relatively abundant in fragmented forests of India surrounded by coffee plantations and where the edge to interior ratio was higher, possibly due to a greater abundance of small mammals and insects in the forest litter. Habitat conditions like these can be found in the mixed oil palm landscape of Solok Selatan of West Sumatra.

We recorded a total of seven small carnivore species in mixed oil palm and forest habitat adjacent to Kerinci Seblat National Park. Carnivore detections comprised only 35 of 2,880 photographs of mammals recorded. Of these, 24 belonged to two species, the common palm civet and Malay civet. Greater canopy closure values were associated with camera-traps recording more species and larger distances from the park edge were also associated with greater species richness at camera-traps, most likely because these species had become isolated in forest surrounded by less unsuitable habitat.

We conclude that mixed oil palm landscape has negatively impacted small carnivore diversity and activity, which has led to the almost complete disappearance of four species (1 photo each out of 2,880 photos). These findings appear consistent with those from other studies regarding the adverse impact of this type of agricultural landscape on the diversity of small carnivores, other terrestrial mammals and biodiversity overall (Mudappa et al., 2007; Fitzherbert et al., 2008; Syamsi, 2011; Bernard et al., 2014; Yue et al., 2015).

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