

Utilisation of gravel roads and roadside forests by the common palm civet (*Paradoxurus hermaphroditus*) in Sabah, Malaysia

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Abstract. We compared the sighting frequencies and habitat use of a mammalian carnivore, common palm civet *Paradoxurus hermaphroditus*, between interior forests, and gravel roads and roadside forests by nocturnal line-transect survey, live-trapping, and radio-telemetry at Tabin Wildlife Reserve in Sabah, Malaysia. The results of line-transect survey and live-trapping demonstrated the frequent use of gravel roads and roadside forests by common palm civets. Radio-telemetry results indicate their preference for roadside forests during their active time. These results suggested their frequent use of the environments around the gravel roads. However given that they did not use roadside forests preferably at daytime, they need dense vegetation for their rest-sites as well. In light of these findings, roads and related deforestation may affect their movements and spatial distribution in a given habitat. Considering proper arrangement of gravel roads is required to minimise impacts on the local mammal communities and to conserve biodiversity.

Key words. Borneo; gravel roads, live-trapping, nocturnal line-transect survey, preference, radio-telemetry

INTRODUCTION

Rainforests in tropical regions are being degraded and lost at an alarming rate (Wright, 2005; Wright & Muller-Landau, 2006). Among tropical regions, Southeast Asia has the highest rates of forest loss and degradation (Sodhi et al., 2004, 2010b; Corlett & Primack, 2011). The main reason for these high loss rates today is a combination of logging and conversion of forest to cash crops, particularly oil palm (Corlett & Primack, 2011; Foster et al., 2011). A number of studies have documented that many vertebrates, particularly mammals, react negatively to habitat changes caused by forest logging or clearing for agricultural land, which increasingly threaten protected areas (Johns & Skorupa, 1987; Curran et al., 2004; Meijaard et al., 2005; Sodhi et al. 2010a).

Forest logging has large scale influence on the natural environment beyond deforestation itself and the indirect effects that accompany forest logging have been highlighted recently (Robinson et al., 1999; Putz et al., 2001; Poulsen et al., 2011; Edwards et al., 2013). For example, development of transportation infrastructure opens forested areas to hunting, illegal mining, and land speculation; such destructive exploitation affect animals at both individual and population

levels (Coffin, 2007; Fahrig & Rytwinski, 2009; Laurance et al., 2009). An increase in the number of road casualties caused by traffic accidents or hunting in tropical regions have been reported in association with the development of linear infrastructure (e.g., Laurance, 2006; Goosem, 2007; Laurance et al., 2009; Sodhi et al., 2010a), which provides easy access to formerly remote areas (Laurance et al., 2009).

Although unpaved roads have less impact on forests and wildlife than paved roads because of their inaccessibility during wet season (Laurance et al., 2001; Fearnside, 2007; Laurance et al., 2009), several studies have documented animal mortality, particularly mammalian carnivores, on gravel or logging roads in Southeast Asia (Colón, 1999, 2002; Mohd Azlan, 2006). Despite their potential threat to animals, the presence of road casualties implies that animals also use the roads. Several studies conducted in Southeast Asia have documented the utilisation of gravel or logging roads by mammalian carnivores such as Malay civets (*Viverra zibetha*) (Colón, 1999, 2002), leopard cats (*Prionailurus bengalensis*) (Sollmann et al., 2013), and Sunda clouded leopards (*Neofelis diardi*) (Wilting et al., 2006; Bernard et al., 2013). This may be due to habits that can benefit from roads—for example, facilitation of movement (Rabinowitz & Nottingham, 1986); utilisation of food resources such as flowers, fruits, and new leaves, the production of which is promoted by higher light levels (Gentry & Emmons, 1987) and herbivorous insects (Fowler et al., 1993); or scent-marking, whereby excrement or secretions are deposited on conspicuous sites such as roads for purposes of olfactory communication (Tsegaye et al., 2008). Therefore, for some mammalian carnivores, gravel roads may facilitate some of their biological needs.

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In this study, we focus on a mammalian carnivore, the common palm civet *Paradoxurus hermaphroditus*. Common palm civets are widely distributed in Southeast Asia (Jennings & Veron, 2009; Patou et al., 2010). They are reported to be strictly nocturnal and highly frugivorous animals (Joshi et al., 1995; Su & Sale, 2007; Nakashima & Sukor, 2010; Nakashima et al., 2010a, b). This species is frequently observed on roads (Pillay, 2009; Low, 2010; Wilting et al., 2010) and often suffer mortality from vehicles (Colón 1999, 2002; Mohd Azlan, 2006; Eng, 2011; Colón & Sugau, 2012); and thus evaluation of its road use is necessary to realise substantial conservation of this species. However, there have been only a few studies demonstrating the use of gravel roads by animals, particularly of nocturnal species (e.g., Mohamed & Sollmann, 2013; Sollmann et al., 2013), and none on the common palm civet. The aim of this study is to investigate the use of roads and roadside environments by the common palm civet using nocturnal line-transect surveys, live-trapping, and radio-telemetry in Tabin Wildlife Reserve, Sabah, Malaysia.

MATERIAL AND METHODS

Study sites. This study was conducted in the Tabin Wildlife Reserve (hereafter called Tabin) in the Malaysian state of Sabah on the island of Borneo. The field surveys were conducted discontinuously from August 2010–September 2011.

Tabin Wildlife Reserve (5°05'–5°22'N, 118°30'–118°55'E) has an area of approximately 1225 km² and is located 50 km northeast of the town of Lahad Datu, eastern Sabah. The reserve is almost exclusively surrounded by large agricultural areas planted with oil palm (*Elaeis guineensis*). Most parts of Tabin were heavily logged in the 1970s and 1980s and are dominated by pioneer species such as *Duabanga moluccana* and *Anthocephalus cadamba* (Mitchell, 1994). The plant species composition at the gravel roadside forests is different from that of the interior forests. We operationally distinguished two areas, roadside forests and interior forests, based on the presence of trees; pioneer plants such as *Anthocephalus cadamba*, *Endospermum diadenum*, *Ficus septica*, *Leea indica*, and *Octomeles sumatrana* which are mostly distributed in areas that are less than 30 m from the gravel roads, and dipterocarp trees, which are abundant in areas more than 30 m from the gravel roads. Therefore, areas located 0–30 m from the sides of the two gravel roads are defined as roadside forests, and the areas located more than 30 m from the gravel roads are defined as interior forests.

The study was conducted near the Sabah Wildlife Department base camp located on the western boundary of Tabin Wildlife Reserve where oil palm plantation is adjacent across the gravel road (Fig. 1), and this area itself was heavily logged at least two times in the 1980s (Mitchell, 1994). A small patchy zone of primary forest remains at Virgin Jungle Reserve No. 83 (74 ha) around Mud Volcano, which is a mound of mud heaved up through overlying sediments, although this forest has also clearly experienced some disturbance (Mitchell, 1994).

In the western border of Tabin Wildlife Reserve, there are two 4 m-wide gravel roads. One of the roads, which lead to Tomanggong village, separate the Tabin Wildlife Reserve forest and oil palm plantation while the other road leads to the central area of Tabin Wildlife Reserve (Fig. 1). During the day, the gravel roads are passible by private vehicles, but at night (from 1800 to 0600 h) only limited numbers of authorised vehicles are allowed to pass through the roads, and speeding cars were often observed at night. The road going to the core area passes through logged forest of varying degrees of regeneration and is not as frequently used as the other road.

Nocturnal line-transect survey. In order to compare the sighting frequency of common palm civets in the interior forest with that along the gravel road, the line-transect method was employed from September–November 2010 and from June–September 2011. We established six transects ranging from 450 to 1350 m in length and totalling 6.5 km in the interior forests (Fig. 1). The location of these transects were chosen to cover the primary forest and surrounding secondary forest areas, avoiding the areas managed by Borneo Rhino Alliance and Sabah Wildlife Department. The edge of each transect was set at least 50 m from the gravel roads. We conducted surveys along these forest trails for 6–14 days per month, each time randomly selecting two of the six transects for surveying. As for surveys along roads, we walked 2 km along either of the two gravel roads.

Each survey was conducted with a minimum of 3-day interval. All surveys and identification were aided by 8×36 binoculars and a 120 lumen headlamp with red filter. Care was taken not to shine lights continuously or directly onto the focal animal. Animals were detected by their reflected eye shines and odours. For this census, we commenced the survey between 1800 and 2000 h, and we walked at a speed of 500–700 m h⁻¹ with frequent, brief stops that allowed careful searching at all heights. If it began to rain, the census was halted until the rain ceased or was aborted completely if it continued to rain heavily. When animals were sighted, the initial location of each animal was marked by eye and perpendicular distance from transect to animal was measured directly to the nearest meter with a measuring tape. Additionally, we recorded the species and the coordinates of each sighting with a global positioning system (GPS76 CSx; Garmin, Kanas, U.S.A.). Because of the small number of encounters with common palm civets (n = 20), density was not calculated. Instead, sighting frequency per 100 km was calculated for each transect. The sighting frequencies at roadside and interior forest areas were compared using a Fisher's exact test.

Prior to comparing sighting frequencies between two habitats (road and interior forests), we evaluated the possibility of bias in detection efficiency because animals occurring in the roadside forests would be easier to detect than those in the interior forests with dense vegetation, and animal occurrence would be differ year by year. We checked the effect of habitat and year covariates on the estimation of detection functions and whether they improve precision of density and abundance

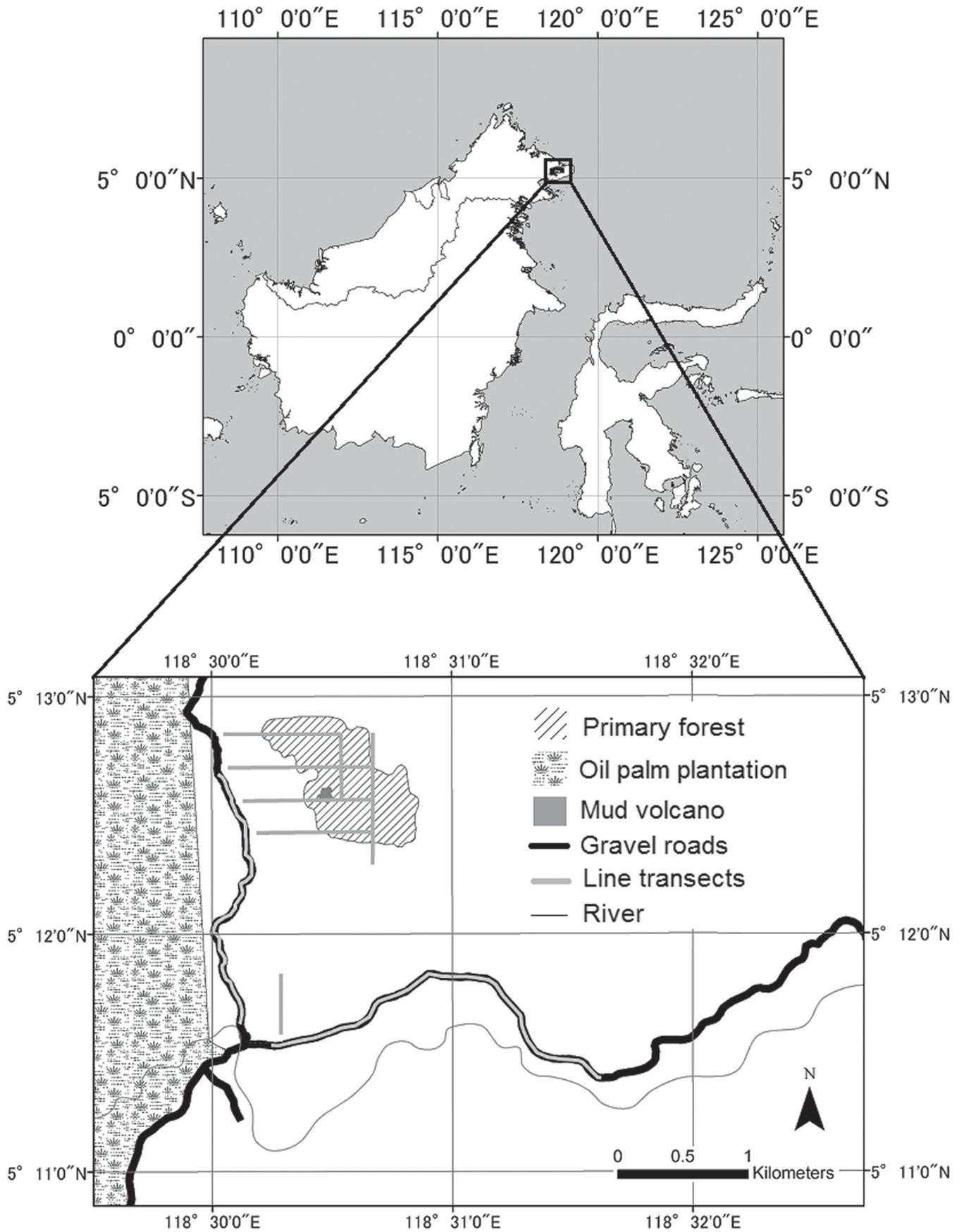


Fig. 1. Schematic view of study area.

Table 1. The sighting frequencies of mammals at night along interior forest transects (70 km) and along gravel road transects (78 km).

Order	Species	No. Observations: Interior Forest	No. Observations: Roadside Forest	Group Size (mean \pm SD)
Carnivora	<i>Paradoxurus hermaphroditus</i>	3	17	1
	<i>Arctictis binturong</i>	0	1	1
	<i>Arctogalidia trivirgata</i>	0	4	1.5 \pm 0.5
	<i>Prionailurus bengalensis</i>	0	8	1
	<i>Hemigalus derbyanus</i>	12	3	1
	<i>Neofelis diardi</i>	0	1	1
	<i>Viverra zangalunga</i>	5	6	1
Artiodactyla	<i>Muntiacus</i> spp.	11	0	1.64 \pm 0.48
	<i>Tragulus</i> spp.	92	0	1.06 \pm 0.25
	<i>Rusa unicolor</i>	4	5	1
	<i>Sus barbatus</i>	5	4	2.11 \pm 1.37
Primates	<i>Hylobates mulleri</i>	0	1	1
Insectivora	<i>Echinosorex gymnurus</i>	2	1	1
Dermoptera	<i>Galeopterus variegatus</i>	1	0	1

estimates using the package “unmarked” (Fiske & Chandler, 2011) of R version 2.14.1 (R Development Core Team, 2013). We fitted the half-normal and hazard-rate detection functions to each model. We also included null models: a model predicting civet density without any covariates. Because of the small sample size of common palm civet sightings to apply these models, we pooled the data for all of the civet species that we detected. Model selection was based on minimisation of Akaike’s Information Criterion (AIC) values, and models with an AIC difference (Δ AIC) <2 from the best model were considered significant and equally supported (Burnham & Anderson, 2002).

Live-trapping. Live-trapping for common palm civets was conducted from August–November 2010 and from June–September 2011. Trapping was carried out using six $60 \times 18 \times 18$ cm portable Havahart brand box traps (Woodstream Corp., Pennsylvania, U.S.A.) and four locally made traps. These were designed with a single door and a foot-activated trigger pad. Traps were baited with mature cultivated fruits (bananas, papayas, jackfruits, small jackfruits), and were set on the ground at dusk and checked each morning. Traps were situated following randomly generated locations, and we set traps at both habitats for at least six trap-nights within a month.

Animal handling protocol in each method described below followed guidelines of the American Society of Mammalogists (Sikes et al., 2011). When civets were captured, the gender and weight were recorded. We also recorded the pattern of marks on the face and scarring of each captured civet for individual identification. The overall capture rates at the roadside forest and the interior forest were compared using a 2-sample test for equality of proportions with continuity correction. In order to avoid bias from recaptured individuals, all recaptures were omitted from the calculation.

Radio-telemetry. The activity of wild common palm civets was tracked with radio-collars (M1940B/ M2940B; Advanced Telemetry Systems, Minnesota, U.S.A.) to determine their habitat use from December 2007–December 2009 (hereafter called period 1; Nakashima et al., 2013), and from August–November 2010 and from June–September 2011 (hereafter called period 2). Only mature animals in good physical condition were selected for telemetry-study and immobilised with 5 mg/kg Zoletil (Vibrac Laboratories, Carros, France) to attach radio-collars (Advanced Telemetry Systems, Minnesota, U.S.A.). The mean collar weights were approximately 40 or 60 g, which were $<3.5\%$ of the animals’ body weight. The locations of the radio-collared civets were estimated by triangulating bearings obtained by observers positioned at GPS mapping stations using receivers and hand-held, four-element Yagi antennas (ATS3EL; Advanced Telemetry Systems, Minnesota, U.S.A.).

During period 1, as the species was confirmed to be strictly nocturnal (Nakashima & Sukor, 2010), tracking was undertaken every 2 hours from 1600 to 0800 h. In addition to this, their day bed sites were also located between 0800 and 1600 h. During period 2, radio-collared individuals were located every 2 hours from 1600 to 0800 h. Civet location was estimated by triangulation using the LOAS software program (Ecological Software Solution, California, U.S.A.). Cumulative ranges were analysed using 95% minimum convex polygon (MCP) methods (Mohr, 1947). To assume location independency, only one location obtained by continuous tracking in the same day was used for home-range analysis. We did not identify captured individuals beyond two periods, so we are not sure about recapture of each tracked civet. However, there is more than a year gap between captures of two periods, and given that common palm civets can shift their home ranges (Nakashima et al., 2013), we considered each captured civet as independent individuals.

Table 2. Summary of detection function model fits.

Covariates	Key Function ^a	ΔAIC
Null	N	0
Year	N	0.40
Null	R	1.92

^aN, half-normal model; R, hazard-rate model
Models with ΔAIC < 2 are shown.

We divided the area of the 95% MCP home range of each civet into two habitats, the roadside forests and the interior forests, and each area was calculated using ArcGIS 10.1 software (ESRI, California, U.S.A.). To evaluate habitat preference, we compared proportion of telemetry fixes of 11 tracked individuals taken at night time in each habitat (used) with proportion of area of each habitat within 95% MCP home ranges of each individual (available), and compositional analysis with randomisation procedure was used (Aebischer et al., 1993). For six individuals tracked during period 1, telemetry fixes taken at daytime were also compared as used habitats with available habitats. When one of the habitats was not used by tracked civets, the value of the unused habitat was replaced by 0.003 to minimise the Type I error rate in compositional analysis (Bingham & Brennan, 2004). All analyses in this section were conducted using the package “Adehabitat” (Calenge, 2006) of R version 2.14.1.

RESULTS

Nocturnal line transect survey. A total distance of 70 km was walked along the interior forest transects and 78 km was walked along the gravel roads. In total, we had 17 common palm civet sightings at the gravel roads and roadside forests, and three at the interior forest transects, respectively. The sighting frequencies per 100 km along the gravel road transects and the interior forest transects were 21.79 and 4.29, respectively. Most common palm civets were detected at the ground (n=13), and three of four civets which were detected on the tree were found lower than 3.5m height. The average perpendicular distances of civets from the transect lines were 12.42 ± 11.95 m (mean \pm SD) at the gravel road transects and 8.33 ± 3.77 m at the interior forest transects. In addition to common palm civets, we detected six other carnivores (*Arctictis binturong*, *Arctogalidia trivirgata*, *Prionailurus bengalensis*, *Hemigalus derbyanus*, *Neofelis diardi*, and *Viverra zangara*), four taxa of artiodactylans (*Tragulus* spp., *Muntiacus* spp., *Sus barbatus*, and *Rusa unicolor*), one primate (*Hylobates mulleri*), one insectivore (*Echinosorex gymnurus*), and one dermopteran (*Galeopterus variegatus*).

The null model using half-normal detection function yielded the lowest AIC (Table 2). However, ΔAIC of models with year as covariate using half-normal detection function, and null models using half-normal and hazard-rate detection functions did not exceed 2, indicating that these three models were equally supported. Therefore, models with habitat as a covariate performed poorly, and thus detection function is unlikely to be affected by habitat. The sighting frequency of common palm civets was significantly higher along the

gravel road transects than along the interior forest transects ($P < 0.01$; Table 1). Because of the small sample size within the interior forests, we did not consider the differences in sighting frequency in primary forest (n=2) and secondary forest (n=1).

Live-trapping. The complete trapping effort represented 672 trap-nights in the roadside forests and 1054 trap-nights in the interior forests; common palm civets were captured 15 times in roadside forests and eight times in the interior forests. In total, 10 and four individuals were captured at the roadside and interior forests sites, respectively. Matured bananas and small jackfruits were especially attractive baits to civets. We captured a juvenile male once at the roadside forests, but we released him after we weighed him without anaesthetisation. Five out of 15 captures at the roadside forest and four out of eight at the interior forest were recaptures (Table 3). Three civets were recaptured once and one female was recaptured twice at the roadside forests, and two female were recaptured twice at the interior forests; we omitted these recaptures from the analysis of capture success rate. The capture-success rate was significantly higher in the roadside forest than in the interior forest ($\chi^2=4.97$, $P < 0.05$).

Radio-telemetry. Six individuals (three males and three females) and five individuals (two males and three females) were fitted with radio-collars during periods 1 and 2, respectively (Table 4). Seven individuals included roadside forest within their 95% MCP home ranges (Fig. 2).

Compositional analysis of the two habitats stratum compared with individual night time home ranges revealed the roadside forests as significantly selected over the interior forests ($\Lambda = 0.238$, $P < 0.05$). On the other hand, that of daytime showed no significant differences between the roadside forests and the interior forests ($\Lambda = 0.257$, $P > 0.1$).

DISCUSSION

Our results showed that common palm civets readily used roadside forests and gravel roads at night time. In the nocturnal line-transect survey, the distance between the gravel road and forest transects was relatively close, so the sighting frequency would reflect both differences in animal density and differences in spatial use by the same individuals. Best-fit models did not include ‘habitat’ as a covariate, suggesting that sighting efficiency may not vary between the roadside and the interior forests. According to previous line-transect surveys conducted in the lowland evergreen dipterocarp forests of Danum Valley Conservation Area in Sabah, Borneo, and on the dirt road traversing the lowland forests with a wide successional gradient vegetation and tree plantations (e.g., *Eucalyptus camaldulensis*) of Khao Ang Rue Nai Wildlife Sanctuary in eastern Thailand, sighting frequencies of common palm civets were 8.3 and 15 per 100 km, respectively (Heydon & Bulloh, 1996, Pliosungnoen et al., 2010). Although these numbers do not always reflect the density of civets at each site and should not simply be compared considering environmental and methodological

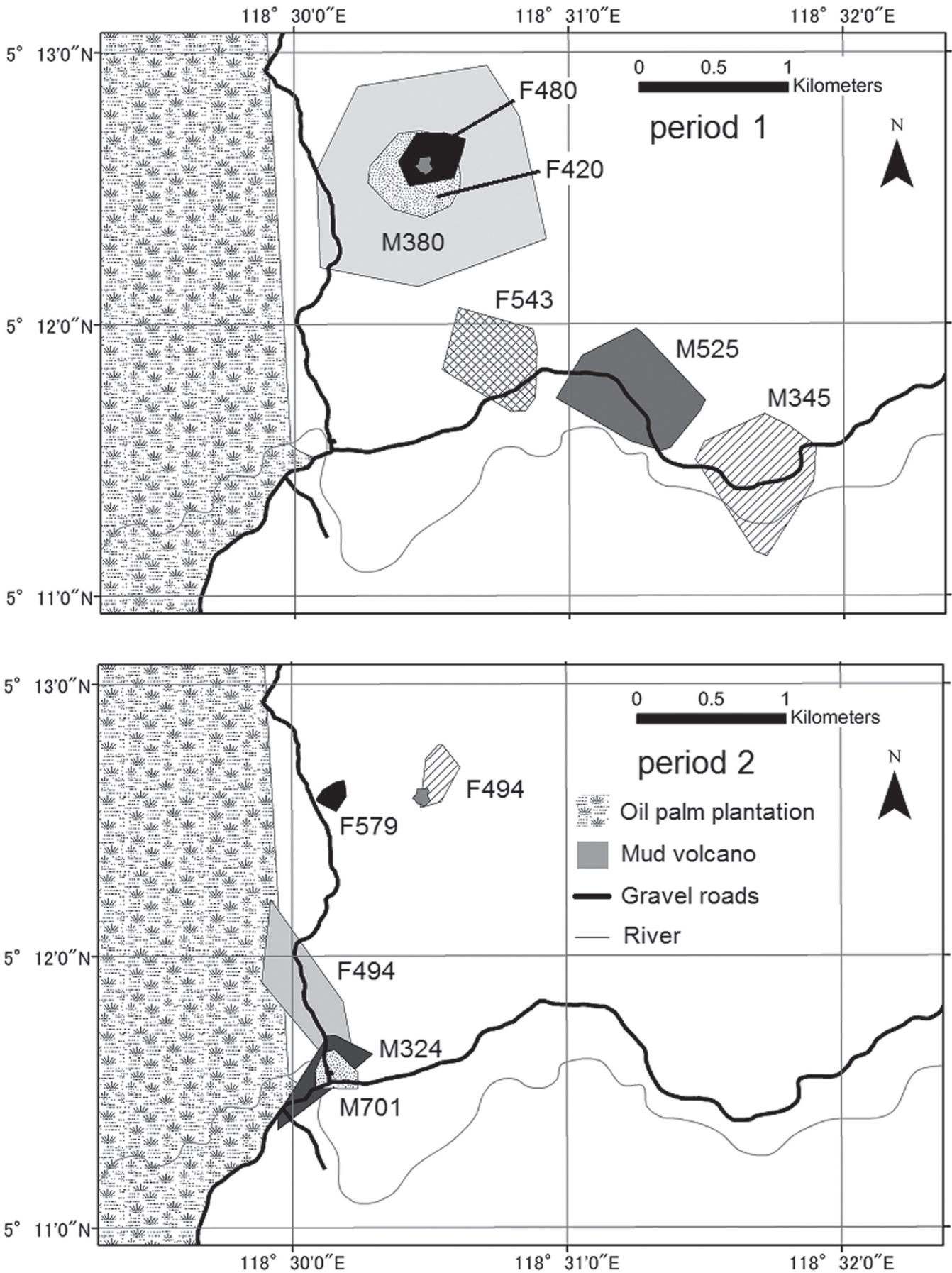


Fig. 2. Distribution of 11 tracked civets during period 1 (December 2007–December 2009) and period 2 (August–November 2010 and June–September 2011).

Table 3. Body measurements of all common palm civets captured in the interior and the roadside forests.

Capture Date	Sex	Head-body Length (cm)	Tail Length (cm)	Weight (kg)	Forest Type	
					Initial Capture	Recapture
10 September 2010	M	60	41	2.5	Roadside	–
10 October 2010	F	53	45	2.1	Roadside	–
10 October 2010	F	50.5	40.5	2.6	Roadside	–
10 October 2010	M	56	46	2.25	Roadside	–
10 October 2010	M	48.5	36.5	2.05	Roadside	Roadside
18 November 2010	F	45	35	2	Roadside	Roadside
19 November 2010	M	–	–	1.05	Roadside	–
5 July 2011	F	–	–	2.6	Roadside	Roadside
7 July 2011	M	57	47	2.4	Roadside	–
9 July 2011	M	53	43.5	2.7	Roadside	Roadside
18 September 2010	F	56	38	1.6	Interior	Roadside
20 July 2011	F	41.5	38.5	1.3	Interior	–
26 July 2011	F	–	–	1.7	Interior	–
3 August 2011	F	45	38	2.4	Interior	–

Table 4. Detail of radio-tracked individuals.

ID	Sex	Weight (kg)	Total Number of Locations	
			Night	Day
M345	M	2.1	31	69
M380	M	2.6	27	80
F420	F	2.1	40	98
F480	F	1.7	21	79
M525	M	1.8	31	104
F543	F	1.8	13	63
M324	M	2.3	18	–
F404	F	2.1	22	–
F494	F	2.4	16	–
F579	F	1.5	51	–
M701	M	2.7	48	–

differences, the available information suggests that the sighting frequency in interior forests (i.e., 4.29 per 100 km) in Tabin Wildlife Reserve was lower than that recorded at other sites. In contrast, sighting frequency at the roadside forests of Tabin Wildlife Reserve (i.e., 21.79 per 100 km) was remarkably higher than that in the interior forests of Tabin Wildlife Reserve or in the other study areas. Similarly, the sighting frequency derived from the survey that was conducted on the dirt road at Khao Ang Rue Nai Wildlife Sanctuary was higher than the interior forests of Tabin Wildlife Reserve and that of Danum Valley Conservation Area. Therefore, based on sighting frequency data, it is likely that the density and spatial use of common palm civets in Tabin Wildlife Reserve may be concentrated along the gravel roads. The results of successful captures and telemetry work conducted at night also indicate that this species prefers roadside forests in Tabin Wildlife Reserve. Similar results were reported in studies using camera traps set along a gravel road and in interior forests at another study area in Sabah, Malaysia (Wilting et al., 2010; Sollmann et al., 2013).

The risk of traffic accidents in addition to the other negative effects associated with gravel roads seems to be significant for wildlife. Many studies indicate that disturbances caused by vehicles have a significant effect on mammal mortality (Laidlaw, 2000; Coffin, 2007; Grilo et al., 2009; Laurance et al., 2009 and references cited therein). The gravel roads in the study area were used as logging roads in the 1970s and 1980s, and are still frequently used by local residents with cars. Three common palm civets were recorded as road kills during the study period (M. Nakabayashi, unpubl. data). Thus, the civets using gravel roads are at risk of being road kills.

Why do the civets use the gravel roads despite the risk of road kill? A peculiar habit of common palm civets may relate to their road use. Considering that telemetry work suggested their preferences for roadside forests only at night, they may appear near the roads during their active time. Several authors reported frequent discoveries of scats along gravel roads (Colón, 1999, 2002; Nakashima et al., 2010b; Colón & Sugau, 2012). In association with this, Wilting et

al. (2010) observed scent-marking individuals on a gravel road during a nocturnal survey. Given the ability of civets to distinguish species, sex, and familiarity by the odour of faeces and perineal gland secretion (Rozhnov & Rozhnov, 2003), they may scent-mark on gravel roads where the detection of faeces and the dissemination of scent would be facilitated. Thus, they probably use roadsides as defecation and communication sites. The distribution of food plants may also influence their use of gravel roads because the availability of their important food plants, *Endospermum diadenum* and *Ficus* spp. (Nakashima et al., 2010a, b), was higher along the roadside forests than in the interior forests (M. Nakabayashi, unpubl. data). For these reasons, it may be reasonable for civets to utilise the roads and roadside forests.

In this study, we found that common palm civets use gravel roads and roadside forests frequently in their active time. Their defecation habits and the distribution of their food plants probably affect their use of gravel roads. Given that roads have an array of deleterious effects on animals and their habitats (Laurance et al., 2009), frequent use of gravel roads and roadside forests indicates that common palm civets have some preference for and adaptability to degraded forests. This tolerance probably enables them to have its large geographical distribution of present-day and to use a wide variety of habitats, including human-disturbed landscapes (Meijaard et al., 2005; Patou et al., 2010; Rustam et al., 2012). However, given that even within common palm civets, three females did not include the gravel roads within their home ranges, the gravel roads should be an important place, but not indispensable for them. Instead of the roadside forests, these females included the Mud Volcano (Fig. 2) in common. The area around the Mud Volcano has some similarities to gravel roads such as canopy openings and a lack of vegetation. Therefore, it is possible that they are preferentially using such environments, and roadside forests are one such example.

Given that common palm civets use dense herbaceous mat as day-bed sites (Nakashima et al., 2013), they need dense vegetation as well. This could be a possible reason why they did not show significant preference for the roadside forests at daytime. In light of these findings, roads may affect their movements and spatial distribution in a given habitat. In Borneo, new concessions are being opened, oil palm schemes are being expanded, and roads are being planned every day (Meijaard & Sheil, 2007). What is required now is the proper arrangement of gravel roads to minimise impacts on the local mammal community and to conserve biodiversity. Reduced-impact logging (RIL) guidelines contain road construction and maintenance in detail, for example, pre-harvest planning of roads, and constructing roads of optimum width (Dykstra & Heinrich, 1996; Sist et al., 1998). Thus, RIL techniques and guidelines should be strictly adhered at existing and planned logging concessions.

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