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Cover: Pseudo-flying animals and wind-dependent seed & spore dispersers – made with digital painting in Krita. © Melito Prinson Pinto

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COMMUNICATION

Small Wild Cats Special Series

Sunda Clouded Leopard *Neofelis diardi* (Cuvier, 1823) (Mammalia: Carnivora: Felidae) occupancy in Borneo: results of a pilot vehicle spotlight transect survey

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Abstract: The Sunda Clouded Leopard *Neofelis diardi* on Borneo is threatened principally by deforestation for oil palm plantations and the indiscriminate use of illegal trapping. Sunda Clouded Leopard populations are decreasing across their range, and the species has been categorised as Vulnerable on the IUCN Red List. Despite the persistence of threats and numerous surveys in recent years, information on its ecology is still limited. Most studies to date have relied on the use of camera traps as their primary sampling tool, as it is challenging otherwise to gather data on Sunda Clouded Leopards. This study aimed to test the feasibility of estimating the Sunda Clouded Leopard occupancy using a different approach. We conducted vehicle spotlight transect surveys in a mixed-use forest reserve and logging concession in Sabah. We drove a cumulative total of 8,433 km of transects at night and documented the occurrence of Sunda Clouded Leopards in eight out of 31 predetermined long-distance transects, yielding a relatively low naïve occupancy rate (nO = 0.26). When accounting for imperfect detection (ρ = 0.15), null occupancy of Sunda Clouded Leopards appeared much higher (ψ = 0.55), though our parameter estimates lacked relative precision. Despite this, our results suggest there may be potential to further refine and adapt a basic, cost-effective monitoring approach in a local mixed-use reserve with the help of concession managers and additional improvements to study design. We caution, however, that not all study sites may be suited for this type of approach and strongly advise the development of pilot studies to evaluate their overall feasibility.

Keywords: Occupancy modelling, selective logging, survey methods, sustainable practices, vehicle transects.

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INTRODUCTION

Information on the biology of species and suitable techniques for their study are often fundamental to their management. An improved understanding of wildlife ecology can lead to more effective conservation strategies (Li et al. 2018) and ultimately prevent a species from going extinct. Among the world's endangered taxonomic groups are large predators (Fritz et al. 2009), which play an essential role in forest ecosystem processes and functioning (Ritchie et al. 2012). The Sunda Clouded Leopard *Neofelis diardi* is the largest obligate predator on Borneo (Matsuda et al. 2008; Payne et al. 1985). It has been categorised as Vulnerable on the IUCN Red List of Threatened Species and is also listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (Hearn et al. 2015).

The Sunda Clouded Leopard lives in a wide range of habitats, including lowland rainforest (Cheyne et al. 2013; Ross et al. 2013; Penjor et al. 2018), primary and selectively logged dipterocarp forest (Brodie et al. 2015; Hearn et al. 2016, 2019) and peat-swamp forest (Cheyne et al. 2013). Segaliud-Lokan Forest Reserve (SLFR) contains a lowland evergreen forest that serves as suitable habitat for the Sunda Clouded Leopard (Wilting et al. 2012). Selective-logging still occurs in this forest and is a practice that may still be compatible with long-term Sunda Clouded Leopard population viability if appropriately managed (Brodie & Giordano 2012). Despite its lower abundance in secondary forest, Brodie et al. (2015) found that Sunda Clouded Leopard habitat use increased toward the ecotones along edges between primary and selectively logged forest. They also found that although primary forest was still the more critical habitat for the Sunda Clouded Leopard, the importance of selectively logged forest to several larger ungulate species, including potential Sunda Clouded Leopard prey, may have provided some additional conservation value to those areas.

A previous survey in SLFR estimated the Sunda Clouded Leopard density in this area to be approximately one individual per 100 km^2 (Wilting et al. 2012), comparable to findings from another study site with a long logging history, the Maliau Basin (1.9 individuals/100 km^2) which occurs in the same general region (Brodie & Giordano 2012). These two studies and subsequent research on the Sunda Clouded Leopard (Bernard et al. 2013a,b; Brodie et al. 2017) all relied on camera trapping as their primary tool to estimate Sunda Clouded Leopard population status. Recent observations of Sunda Clouded Leopards made by staff and management in SLFR suggested that spotlight vehicle transects might be possible for investigating Sunda Clouded Leopard behaviour and activity. This observation was made during the initial site visit, when conversations first occurred between researchers, SLFR staff and management.

We conducted the first known pilot survey for Sunda Clouded Leopards using spotlight vehicle transects, with the objective of estimating occupancy and detection probability for the population in SLFR. We did this partly to evaluate the efficacy and feasibility of this approach, which has been used on felids and other carnivores elsewhere, to assess the occupancy of a 'large' tropical forest felid on Borneo. We also hoped to further understand the impact of various habitat and anthropogenic features on Sunda Clouded Leopard occupancy. We think that our findings have value for understanding how this methodology can be used in this type of habitat, as well as important conservation implications for reserve management and adjacent land uses.

Study Area

Segaliud Lokan Forest Reserve (SLFR) is a private logging concession located north-east of Deramakot Forest Reserve in the District of Sandakan, part of the Malaysian state of Sabah (Figure 1). Gazetted in 1955, the SLFR is approximately 570 km^2 (KTS Plantation 2019) and was subject to a conventional logging system until the mid-late 1990s (Wilting & Mohamed 2010). In 1994, the reserve's management was taken over by KTS Plantation Sdn Bhd and in 1998, a reduced impact logging (RIL) system was introduced to mitigate the potentially negative impacts of logging on native vegetation and wildlife (Yap et al. 2015). Today the SLFR consists of logged hill dipterocarp forests that provides refuge for many important threatened fauna in Borneo, including the Bornean Pygmy Elephant *Elephas maximus borneensis*, Tembadau, Bornean Orangutan *Pongo pygmaeus* and hornbills (KTS Plantation 2019).

MATERIALS AND METHODS

Data collection

We used a vehicle-based spotlight survey method (e.g. Henschel et al. 2016) to detect the presence of Sunda Clouded Leopards along logging roads in dense vegetation forest (Driessen & Hocking 1992). We spent 20 days each month conducting these surveys between October 2017 and December 2018. As this carnivore is

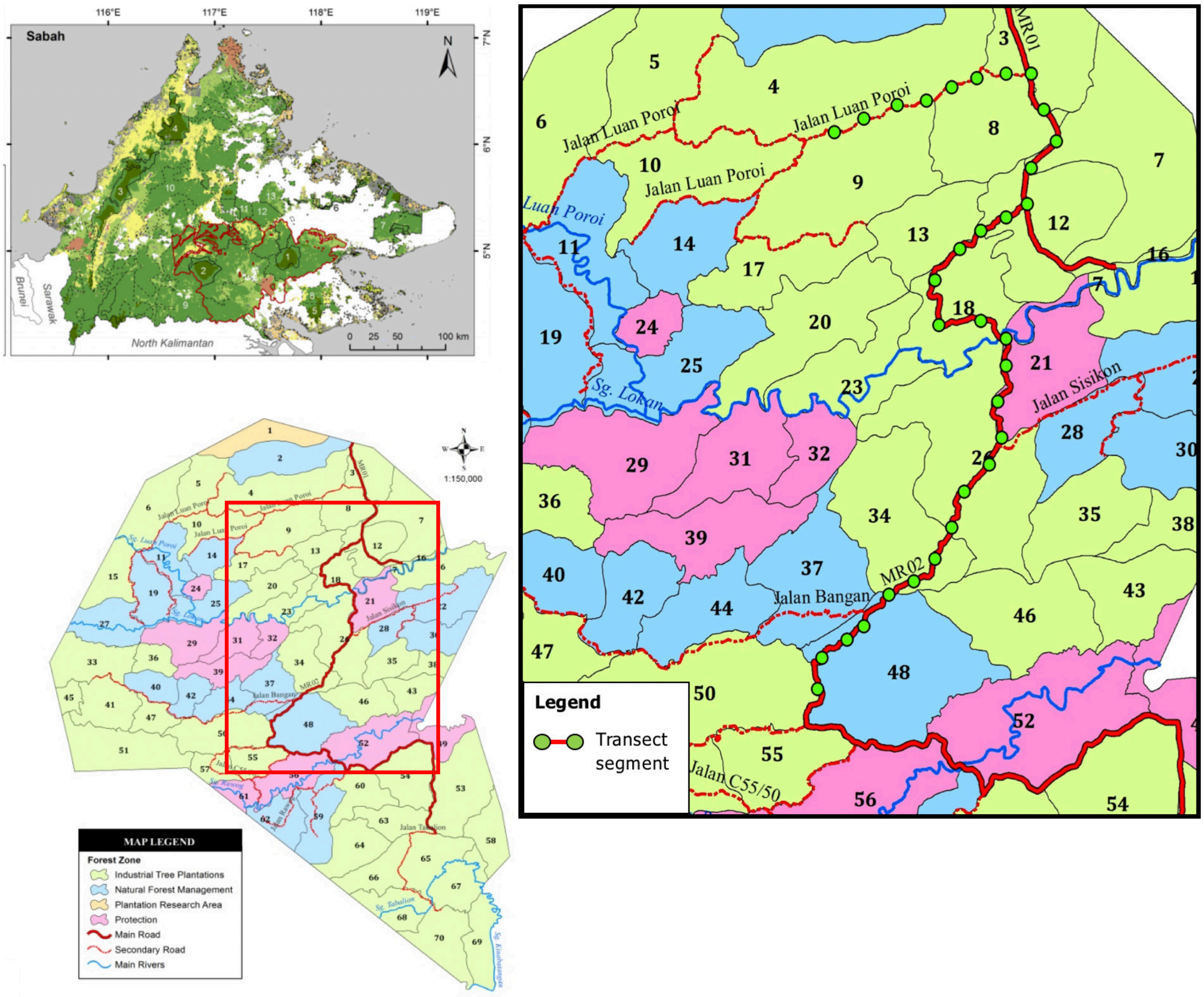

Figure 1. Location of Segaliud-Lokan Forest Reserve in Sabah, Malaysia (Source: KTS Plantation Sdn Bhd, 2011).

primarily nocturnal (Cheyne & Macdonald 2011; Brodie & Giordano 2012; Ross et al. 2013), all surveys were conducted at night between 1900 h and 2300 h. The survey team consisted of three persons: one person manned the vehicle, another person acted as a spotter using the spotlight, and the third person recorded all observations systematically. Dirt and gravel logging roads were targeted for surveys, as these were favourable pathways for the movement of Sunda Clouded Leopards (Wilting et al. 2006; Gordon & Stewart 2007; Brodie & Giordano 2012). When driving transects, we followed Roberts et al. (2006) in maintaining an average speed of 16–24 km/h.

In total, we established a 31 km spotlight "trail" (Figure 1) through primary and secondary logging roads, on which prior sightings of Sunda Clouded Leopards were reported by local staff. The total trail was divided into 31 distinct 1-km transect segments, along which each sighting of a Sunda Clouded Leopard was treated independently. To determine coarse-scale habitat use by the Sunda Clouded Leopard, we established and systematically sampled ten vegetation plots, each 10 m x 10 m in area along the forest's edge for every 1-km transect segment. Five pairs of vegetation plots were established, one on each side of the road, with intervals between adjacent plots on the same side ranging from 150 to 200 m (Figure 2).

To help characterise habitat in each plot, we recorded six variables, namely (1) tree species diversity, (2) slope, (3) percentage of understory vegetation cover, (4) percentage of canopy closure, (5) number of trees with diameter at breast height (DBH) > 10 cm, and (6) number of trees with DBH less than 10 cm (Table 1).

Data analysis

Our objectives were to estimate site occupancy and

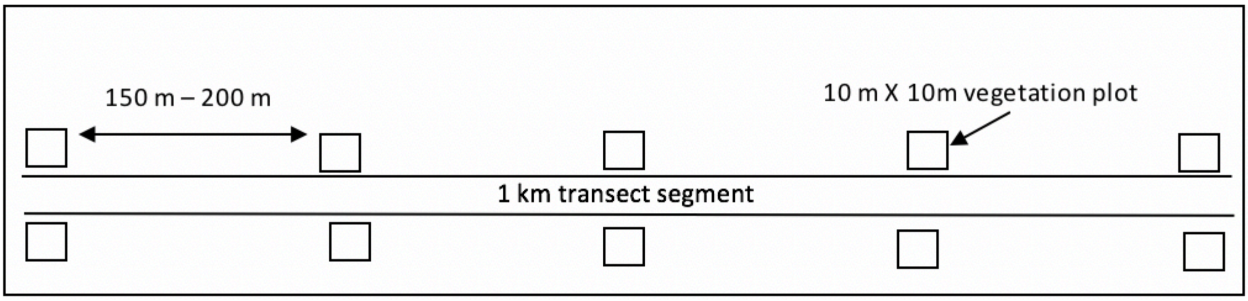

Figure 2. Vegetation plots established at 1 km transect segment.

the detection probability of Sunda Clouded Leopards in SLFR. We defined naïve occupancy (nO) for the entire sampling period as the ratio of sites where Sunda Clouded Leopards were sighted over the total number of sites surveyed. The site occupancy parameter (ψ) is defined as the estimated proportion of sites occupied by Sunda Clouded Leopards within our given area of inference (Mackenzie et al. 2006). Site occupancy (ψ) incorporates a distinct estimate of detection probability (ρ) as a way to model or account for "false absences" (Mackenzie et al. 2006), whereby a Sunda Clouded Leopard may be present but not detected in a segment or "site" during our survey. We used a single-season, single-species occupancy model to analyse all collected data and completed all analyses using the "Unmarked" package of Program R (R Development Core Team 2018).

RESULTS

We travelled 8,433 km in total of for all of our vehicle spotlight surveys, during which time we recorded 14 independent records of Sunda Clouded Leopards (Image 1). Individual Sunda Clouded Leopards were detected each month of the study period except February and March of 2019, for an average of one detection every 602.36 km. Overall we sighted Sunda Clouded Leopards in eight out of the 31 transect segments (Figure 3).

The average measurements for our vegetation sampling plots were as follows: (1) understory coverage = 79.34 ± 1.26% (mean ± SE); (2) canopy closure = 31.68 ± 2.60%; (3) stems and trunks = 325.00 ± 16.42 per ha; (4) tree seedling density = 315.81 ± 14.98 per ha; and (5) Shannon-Weiner diversity index of 2.16 ± 0.05 species per plot. The slope across sampled plots ranged from flat to slightly steep (<20̊).

Based on our raw data, our overall naïve occupancy rate for the Sunda Clouded Leopard was relatively low (nO = 0.26). However, our estimate of null site occupancy (ψ) was more than twice as high (ψ = 0.55 ± 0.31; Table 2) as naïve occupancy, which suggests that the Sunda Clouded Leopard might use more than half of the sites in our transect. This discrepancy is probably because our estimate for null detection probability (ρ) was also very low (ρ = 0.14 ± 0.09) using this novel sampling methodology.

We also note that the precision for our null model estimate of site occupancy (ψ) was also very low, and that naïve occupancy (0.26) fell within one standard error of this estimate (0.24–0.86), albeit at the low end. Although we evaluated seven coarse-scale habitat models based on microhabitat variable we collected (Table 3), we found no evidence that these microhabitat variables significantly affected or were associated with Sunda Clouded Leopard occupancy (p >0.05). Moreover, we found that all detection probability estimates for all models were low and varied very little (0.09 < ρ < 0.15). Therefore, based on the spotlight transect sampling approach and sample size we achieved, none of the covariates we assessed for this pilot appeared to influence detection probability (ρ).

DISCUSSION

Although our estimate of ψ (0.55) for SLFR's Sunda Clouded Leopard population was twice as much as that for naïve occupancy (nO = 0.26), we acknowledge that our sample size, even over 14 months, and our precision (± 0.31) relative to our estimate, was too low to be of practical use for monitoring or similar purposes. Unsurprisingly, all estimates of detection probability (ρ) were relatively low using this method (<0.15). Among the prominent factors that may have contributed to a low detection probability (ρ) for Sunda Clouded Leopards included the type and kind of vegetation adjacent to the road as potentially impacting observability or visibility; additionly, individual behaviour such as inter-individual

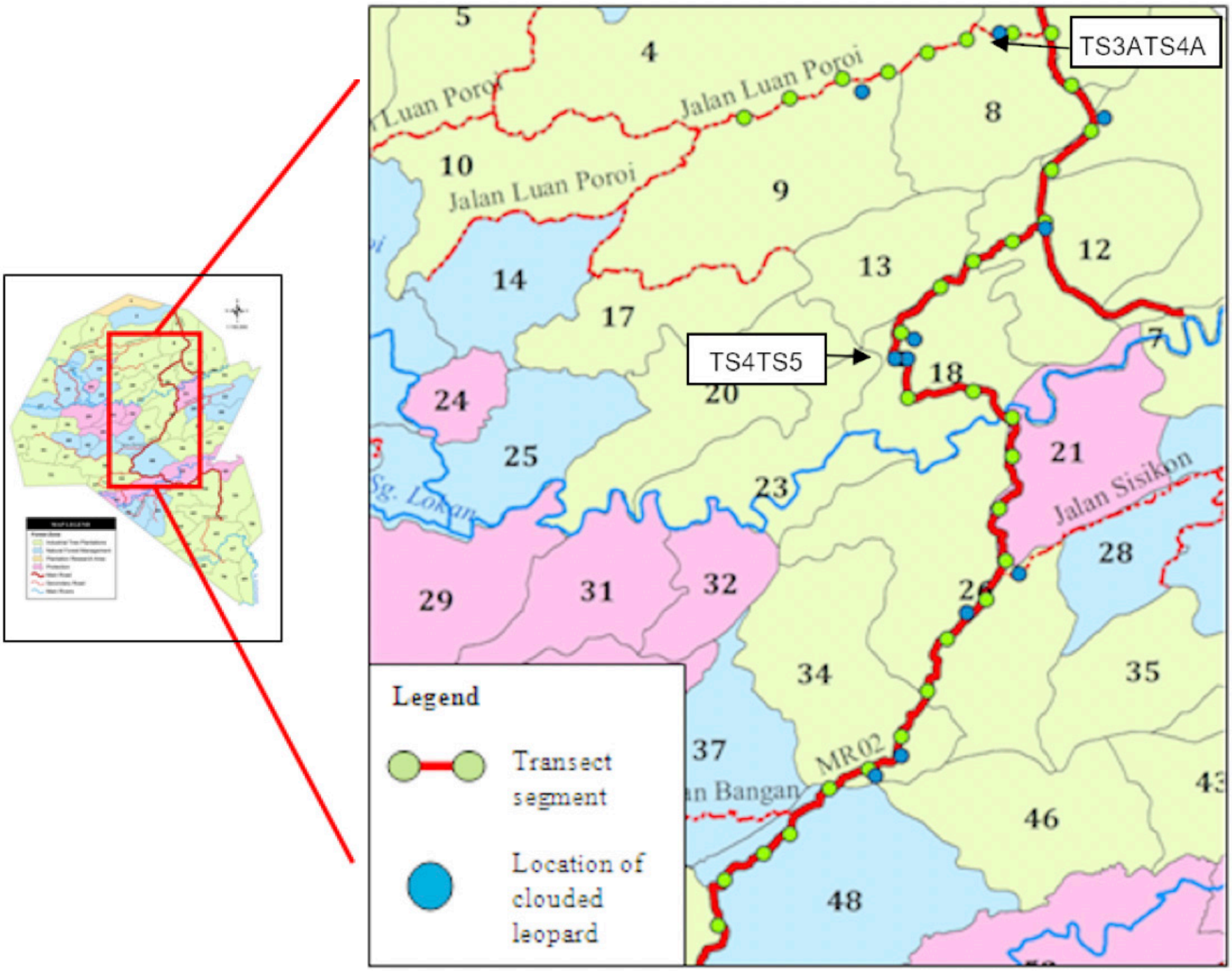

Figure 3. Location of Sunda clouded leopard observations along our 31 1-km transects.

Table 1. Habitat variables used in our investigation of Sunda Clouded Leopard occupancy in Segaliud Lokan Forest Reserve.

Habitat variables	Descriptions
Diversity of tree	Index of tree species diversity within the plot (diameter at breast height, or DBH of ≥10 cm) as calculated via the Shannon's Diversity Index.
Tree density	Tree density measured by the number of trees recorded with a DBH ≥10 cm per area.
Sapling/Seedling density	Sapling density refers to the number of trees recorded with a DBH ≤10 cm per area.
Slope	Slope measured by clinometers, and categorized as 0 (flat, 0–10°), 1 (slightly steep, 11°–20°), and 2 (steep, >20°).
Canopy closure (%)	Canopy closure % as measured using a densiometer; five canopy closure readings were taken for every transect segment.
Understory vegetation cover (%)	Estimated percentage of understory vegetation coverage, including grass, shrubs, and fern, by using visual assessment. This assessment was adapted from Chaves et al. (2016)

variability in response to vehicle noise, weather and sky conditions during and before the nights of sampling (Henschel et al. 2016) may have also played a role. Other factors that could have influenced Sunda Clouded Leopard activity and occupancy included the moon phase (Ampeng et al. 2018), and local prey availability (Bhatt et al. 2021; Ross et al. 2013). These potential covariates remain to be explored further to adapt our design, make it more efficient, and hopefully result in larger sample sizes during future surveys.

Of course, camera trapping surveys are still an optimal means to model medium-large terrestrial wildlife occupancy. However, we saw value in exploring this alternative approach at the behest of reserve management personnel given their previous and regular anecdotal observations. Based on the pilot data we collected, we think the integration of both camera trapping and vehicle transects would yield interesting comparisons for the whole area of SLFR. Increasing our

Table 2. Site occupancy parameter (ψ) estimate using vehicle transects for Sunda Clouded Leopard in Segaliud Lokan Forest Reserve, Sabah, Malaysia.

Occupancy model	K [1]	AIC [2]	ΔAIC [3]	ω [4]	ψ ± SE [5]	Estimate ± SE [6]	p-value [7]
ρ(.) ψ(Slope)	3	70.16	0.00	0.373	0.56 ± 0.31	– 0.258 ± 1.270	0.839
ρ(.) ψ(Sapling)	3	71.05	0.89	0.239	0.63 ± 0.38	0.514 ± 1.620	0.751
ρ(.) ψ(Diversity)	3	71.87	1.71	0.158	0.55 ± 0.31	0.186 ± 1.270	0.883
ρ(.) ψ(.)	2	72.69	2.53	0.105	0.55 ± 0.31		
ρ(.) ψ(Understory vegetation cover)	3	74.34	4.18	0.046	0.58 ± 0.34	– 0.343 ± 0.607	0.572
ρ(.) ψ(Density)	3	74.65	4.50	0.039	0.52 ± 0.30	– 0.490 ± 0.848	0.860
ρ(.) ψ(Canopy)	3	74.69	4.53	0.039	0.54 ± 0.30	– 0.143 ± 1.200	0.906

Note: [1] Number of parameters estimated, [2] Akaike information criterion, [3] Difference in AIC value relative to the top model, [4] AIC weight, [5] Averaged occupancy and SE values, [6] Coefficient of predictors in logit scale, and [7] significant level at 0.05.

Table 3. Detection probability (ρ) estimates using vehicle transects for Sunda Clouded Leopard in Segaliud Lokan Forest Reserve, Sabah, Malaysia.

Detection model	K [1]	AIC [2]	ΔAIC [3]	ω [4]	p ± SE [5]	Estimate ± SE [6]	p-value [7]
ρ(.) ψ(.)	2	72.69	0.00	0.290	0.14 ± 0.09		
ρ(Slope) ψ(.)	3	74.19	1.51	0.130	0.10 ± 0.03	– 0.320 ± 0.460	0.490
ρ(Sapling) ψ(.)	3	74.32	1.63	0.130	0.10 ± 0.03	0.240 ± 0.370	0.523
ρ(Understory vegetation cover) ψ(.)	3	74.47	1.78	0.120	0.15 ± 0.09	– 0.163 ± 0.343	0.634
ρ(Canopy) ψ(.)	3	74.49	1.80	0.120	0.14 ± 0.09	– 0.190 ± 0.430	0.662
ρ(Density) ψ(.)	3	74.52	1.84	0.110	0.14 ± 0.09	0.200 ± 0.550	0.717
ρ(Diversity) ψ(.)	3	74.68	2.00	0.110	0.09 ± 0.03	– 0.010 ± 0.460	0.982

Note: [1] Number of parameters estimated, [2] Akaike information criterion, [3] Difference in AIC value relative to the top model, [4] AIC weight, [5] Averaged detection and SE values, [6] Coefficient of predictors in logit scale, [7] significant level at 0.05.

effort during a single survey occasion, such as broadening transect coverage or using multiple survey teams, might increase the probability of detecting individual Sunda Clouded Leopards. Our pilot survey therefore serves as a starting point and provides a baseline, upon which to further develop tools for monitoring Sunda Clouded Leopards and their prey at multi-use forest plantations.

Finally, we would like to emphasise that another goal of this pilot study was that it serve as a practical, first-hand, participatory exercise for the staff of an extractive timber reserve, where selective logging still occurs today. As such, it represented the kind of experiential learning program that generally proves more effective than more traditional awareness campaigns or approaches (Higginbottom 2004). It also highlighted the challenges of using observations, however reportedly frequent based on anecdotal previous reports, as a tool for monitoring a nocturnal rainforest predator. By sharing these practical conclusions with the Sabah Wildlife and Sabah Forestry Departments, both of which had indicated an interest in our findings, we also hope we were able to better inform their own planning and decision-making as they applied these to other forest management areas.

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Image 1. Sunda Clouded Leopards recorded in Segaliud Lokan Forest Reserve during vehicle spotlight survey: a—found in TS4TS5 | b—was found in TS3ATS4A.

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Malay Abstrak: Harimau Dahan Sunda Neofelis diardi di Borneo terancam yang terutamanya disebabkan oleh penebangan hutan untuk ladang kelapa sawit dan aktiviti perangkap haram. Populasi Harimau Dahan Sunda semakin berkurangan dan spesies ini telah dikategorikan sebagai mudah terdedah dalam Senarai Merah IUCN. Walaupun ancaman berterusan dan banyak tinjauan dalam beberapa tahun kebelakangan ini, namun maklumat mengenai ekologinya masih terhad. Kebanyakan kajian sehingga kini bergantung kepada penggunaan perangkap kamera sebagai alat pensampelan utama disebabkan mengumpul data tentang Harimau Dahan adalah mencabar. Kajian ini bertujuan untuk menguji kebolehlaksanaan menganggarkan Harimau Dahan Sunda menggunakan pendekatan berbeza. Kami menjalankan tinjauan transek lampu sorot kenderaan di hutan simpan guna-campuran dan konsesi pembalakan di Sabah. Kami memandu sejumlah 8,433 km transek pada waktu malam dan mendokumentasikan penemuan Harimau Dahan Sunda dalam lapan daripada 31 transek jarak jauh yang telah ditetapkan, menghasilkan kadar penghunian naif yang agak rendah (nO = 0.26). Apabila mengambil kira pengesanan tidak sempurna (ρ = 0.15), penghunian null Harimau Dahan Sunda kelihatan jauh lebih tinggi (ψ = 0.55), walaupun anggaran parameter tidak mempunyai ketepatan relatif. Walaupun begitu, keputusan kami mencadangkan mungkin terdapat potensi untuk memperhalusi dan menyesuaikan pendekatan pemantauan asas dan kos efektif dalam rizab penggunaan campuran tempatan dengan bantuan pengurus konsesi dan penambahbaikan tambahan untuk reka bentuk kajian. Walaubagaimanapun, adalah ditekankan bahawa tidak kesemua tapak kajian mungkin bersesuaian dengan jenis pendekatan ini dan sangat menasihati pembangunan kajian rintis untuk menilai kebolehlaksanaan keseluruhannya.

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