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Predicted distribution of the common palm civet *Paradoxurus hermaphroditus* (Mammalia: Carnivora: Viverridae) on Borneo

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Wilting et al. (2016: Table 2) list all co-authors' affiliations.

Abstract. The common palm civet *Paradoxurus hermaphroditus* is a small carnivore occurring in a broad array of habitats on Borneo, including logged and unlogged forest, cultivated land, and the outskirts of villages and towns. It is assigned incomplete legal protection in Indonesia and Brunei Darussalam. In addition, the recent, rapidly expanding increase in capture for use in civet coffee production, especially in Indonesia, might adversely affect its population. We used 67 (Balanced Model) and 113 (Spatial Filtering Model) occurrence records within a MaxEnt niche distribution modelling approach to predict its current possible distribution on Borneo. A large proportion of Borneo is predicted to be suitable habitat, including human-modified areas such as plantations. Predicted suitability was lower in coastal regions. Despite its high adaptability to habitat change, conservation actions for this species might be needed because it is widely caught for the production of civet coffee and killed as a pest or for meat. Further research is needed to investigate how these legal and illegal activities affect the common palm civet populations.

Key words. Borneo Carnivore Symposium, Brunei, conservation priorities, habitat suitability index, Indonesia, Malaysia, species distribution modelling, survey gaps

Abstrak (Bahasa Indonesia). Musang Luwak *Paradoxurus hermaphroditus* adalah karnivora kecil dengan sebaran yang luas di Asia juga memiliki habitat yang luas di Borneo, mulai dari hutan primer, hutan bekas tebangan, perkebunan, lahan pertanian dan bahkan di pemukiman. Jenis ini tidak dilindungi di Indonesia dan Brunei Darussalam. Bahkan akhir-akhir ini penangkapan jenis ini di alam meningkat yang digunakan untuk produksi kopi luwak, terutama di Indonesia, yang akan berpengaruh terhadap jumlah populasinya. Kami membuat Pemodelan Sebaran Niche MaxEnt dengan menggunakan 67 (Model Penyeimbang) dan 113 (Model Spasial Tersaring) dari catatan kehadiran jenis ini untuk memprediksi sebarannya saat ini di Borneo. Hasil penelitian menunjukkan bahwa sebagian besar kawasan di Borneo dianggap habitat yang sesuai untuk Musang Luwak, termasuk daerah-daerah yang telah diubah menjadi peruntukkan lain, seperti kawasan perkebunan. Pengecualian untuk kawasan pesisir yang diprediksi sebagai kawasan yang kurang sesuai untuk habitat Musang Luwak. Hasil ini juga menunjukkan bahwa ancaman terhadap konservasinya rendah. Namun, bukan berarti bahwa aksi konservasi untuk jenis ini tidak diperlukan karena diketahui secara luas bahwa Musang Luwak ditangkap dan gunakan untuk produksi kopi luwak, dibunuh karena dianggap sebagai pemangsa unggas dan dibunuh untuk dimakan. Penelitian lebih lanjut diperlukan untuk mengetahui pengaruh aktivitas manusia baik legal maupun illegal terhadap populasi Musang Luwak.

Abstrak (Bahasa Malaysia). Musang Pulut/ Musang Luwak *Paradoxurus hermaphroditus* adalah seekor karnivora kecil yang berada di pelbagai habitat termasuk hutan yang sudah dibalak dan yang belum dibalak, perladangan, dan kawasan pinggir kampung, di Borneo. Spesis ini tidak terlindung sepenuhnya di Indonesia dan Brunei Darussalam. Namun, peningkatan kejadian pemburuan haram baru-baru ini untuk industri kopi musang (kopi luwak), terutamanya di Indonesia, mungkin ada kesan buruk terhadap populasinya. Di sini, kami menggunakan 67 (Model Seimbang) dan 113 (Model yang ditapis secara spasial) rekod penemuan spesis ini dalam pendekatan model penyebaran (distribusi) ceruk (niche) MaxEnt untuk meramalkan distribusi spesis ini di seluruh Borneo. Model kami meramalkan sebahagian besar Borneo terdiri daripada habitat yang sesuai bagi Musang Luwak, termasuk kawasan yang diubahsuaikan oleh manusia seperti perladangan, dan ini menunjukkan ancaman pemuliharaan peringkat rendah terhadap spesis ini. Namun demikian, keputusan model kami tidak bererti tiada keperluan untuk mempertimbangkan tindakan pemuliharaan bagi spesis ini kerana pemburuannya berleluasa untuk memenuhi keperluan industri kopi luwak dan sebagai haiwan perosak (pest) serta untuk dagingnya. Kajian yang lebih mendalam perlu dilakukan untuk menilai kesan aktiviti pemburuan terhadap populasi Musang Luwak.

INTRODUCTION

The common palm civet *Paradoxurus hermaphroditus* (Pallas), is a small carnivore (1.7–2.7 kg) which lives in Borneo in a broad array of habitats, including logged and unlogged forest, cultivated land, and the outskirts of villages and towns (Stuebing & Gasis, 1989; Yasuma & Andau, 2000). Common palm civets from across the world range – South Asia and South-east Asia – have typically been considered to be one species (e.g., Corbet & Hill, 1992). Veron et al. (2015), however, suggested that the three major clades found by Patou et al. (2010) should be recognised as different species. The common palm civets inhabiting Borneo (Fig. 1) would then be classified together with those from the Mentawai Islands and the Philippines as *P. philippinensis* Jourdan. On Borneo, the species is described as solitary, nocturnal and frugivorous (Nakashima et al., 2010a). It disperses large seeds over much longer distances than do other disturbance-tolerant frugivores, such as macaques *Macaca* Lacépède, in degraded habitats (Nakashima et al., 2010b). It also consumes prey such as insects, millipedes and small vertebrates (Nakashima et al., 2010a). Males were observed to have larger home range size (79 ha; 95% kernel) than females (29 ha) in heavily logged forests of Sabah, Borneo (Nakashima et al., 2013).

This species is classified as Least Concern by The IUCN Red List of Threatened Species (Duckworth et al., 2008) because of its large population size, resilience to anthropogenic disturbance, and use and tolerance of a broad range of habitats. Legal protection in Borneo varies across countries. In Indonesia, the species is not protected by law (Shepherd, 2012), and in Brunei, it is not included in the country's Wildlife Protection Act. In the Malaysian states of Sabah and Sarawak, it is listed as protected under the Wildlife Conservation Enactment 1997 of Sabah and Wildlife Protection Ordinance 1998 of Sarawak, respectively. It is unknown to what degree the recent and increasing rise in legal and illegal capture for use in civet coffee, especially in Indonesia (D'Cruze et al., 2014; Nijman et al., 2014), threatens the common palm civet. In this study we used a MaxEnt niche distribution modelling approach to predict its current potential distribution and habitat suitability on Borneo, and discuss potential conservation and research needs for this species.

RESULTS AND DISCUSSION

Species occurrence records. In total, 417 occurrence records were obtained fairly evenly from across Borneo (Fig. 2) with the exception of the central, mountainous regions.

Fig. 1. A common palm civet *Paradoxurus hermaphroditus* photographed in Tabin Wildlife Reserve, Sabah, Malaysia, on 20 November 2009 (Photograph by: M. Nakabayashi).

Of 417 records, 155 (37.2%) had exact locations and were made between 2001 and 2011. However, Sabah provided the majority of the records, so records were systematically reduced to 67 (Balanced Model M_1) or 113 (Spatial Filtering Model M_2) for modelling (Table 1; see Kramer-Schadt et al. (2016) for methods).

Habitat associations. Based on the opinions of 13 respondents, lowland forest was considered to be suitable habitat for this species, with scores ranging from 3 (good) to 4 (very good) (Table 2). The least suitable land-cover classes were adjudged to be water, water and fishponds, and bare areas which ranged from 0 (unsuitable) to 1 (very poor). The remaining land-cover classes such as upper montane forest, swamp forest, mangrove, and mixed crop were categorised inconsistently among the respondents, with scores ranging from 0 to 4.

Habitat suitability index (HSI) model. The model suggests that most of Borneo consists of suitable habitat for the common palm civet (Fig. 3). Southern coastal regions were classified as least suitable habitat, probably because these regions comprise extensive peat swamp forest (Langner & Siegert, 2006), a habitat considered to be less suitable for the species by the respondents (Table 2). In addition to protected areas, much unprotected land, especially in Sabah, Sarawak, and East Kalimantan was predicted to be highly suitable. Thus, no protected areas or regions can be flagged as of particular importance for conservation for the common palm civet.

Brunei Darussalam. Most of the country was predicted as suitable habitat for the common palm civet. There were no spatially precise records from this country; this is likely to reflect the lower search effort rather than an actual absence of the species.

Sarawak, Malaysia. Most records were from outside protected areas and mainly from plantations. Large percentages of the state's forests and anthropogenic habitats

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Table 1. Summary of the occurrence records for common palm civet *Paradoxurus hermaphroditus* on Borneo.

Spatial Precision	Total No. of Records	No. of Records in M_1	No. of Records in M_2	No. of Recent Records 2001–2011
Category 1 below 500 m	155	30	49	155
Category 2 500 m – 2 km	18	5	10	8
Category 3 2–5 km	121	32	54	15
Category 4 above 5 km	70	–	–	3
Category 5 (no coordinates*)	53	–	–	1
Total	**417**	**67**	**113**	**182**

M_1 = Balanced Model; M_2 = Spatial Filtering Model (10 km); *only coarse location description was available.

Table 2. Land-cover reclassification for common palm civet *Paradoxurus hermaphroditus* based on the questionnaire results of 13 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.62	3–4
Upland forest	3.10	2–4
Lower montane forest	2.60	1–4
Upper montane forest	1.80	0–4
Forest mosaics/lowland forest	3.47	*
Forest mosaics/upland forest	3.21	#
Swamp forest	2.36	0–4
Mangrove	1.50	0–4
Old plantations	3.34	2–4
Young plantations and crops	2.10	1–4
Burnt forest area	0.70	0–3
Mixed crops	1.70	0–4
Bare area	0.18	0–1
Water and fishponds	0.09	0–1
Water	0	0–0

*/#Calculated based on the mean of the reclassification of old plantation and *lowland forest or #upland forest, respectively.
Habitat suitability rank ranges from 0 (unsuitable) to 4 (most suitable); further detail, and on land-cover classes, in Kramer-Schadt et al. (2016).

were predicted to be moderately to highly suitable for this species except for the coastal region where mangroves are distributed.

Sabah, Malaysia. As with Sarawak, most of Sabah outside the coastal region was predicted to be suitable. This includes the large areas of oil palm plantations.

South Kalimantan, Indonesia. A large proportion of southern South Kalimantan was predicted to be unsuitable while the north was predicted to be moderately suitable. South Kalimantan is more seasonal than the rest of Borneo, with a pronounced dry season. These different climatic conditions are likely to have resulted in a lower prediction of suitable habitat because only one record from South Kalimantan was sufficiently precise for modelling. This paucity of records might well reflect low survey effort rather than a true scarcity of the species. More extensive surveys could confirm its distribution and population status in this province.

Central Kalimantan, Indonesia. Most of southern Central Kalimantan, including the extensive peat swamp forests and heath forests, was predicted to be moderately suitable to unsuitable habitat. Most forested areas in northern Central Kalimantan were predicted to be highly suitable. Observation records were obtained from both these areas.

North Kalimantan and East Kalimantan, Indonesia. Most areas of these provinces were predicted to be suitable, except for the large deltas of the Sungai [=River] Kayan in

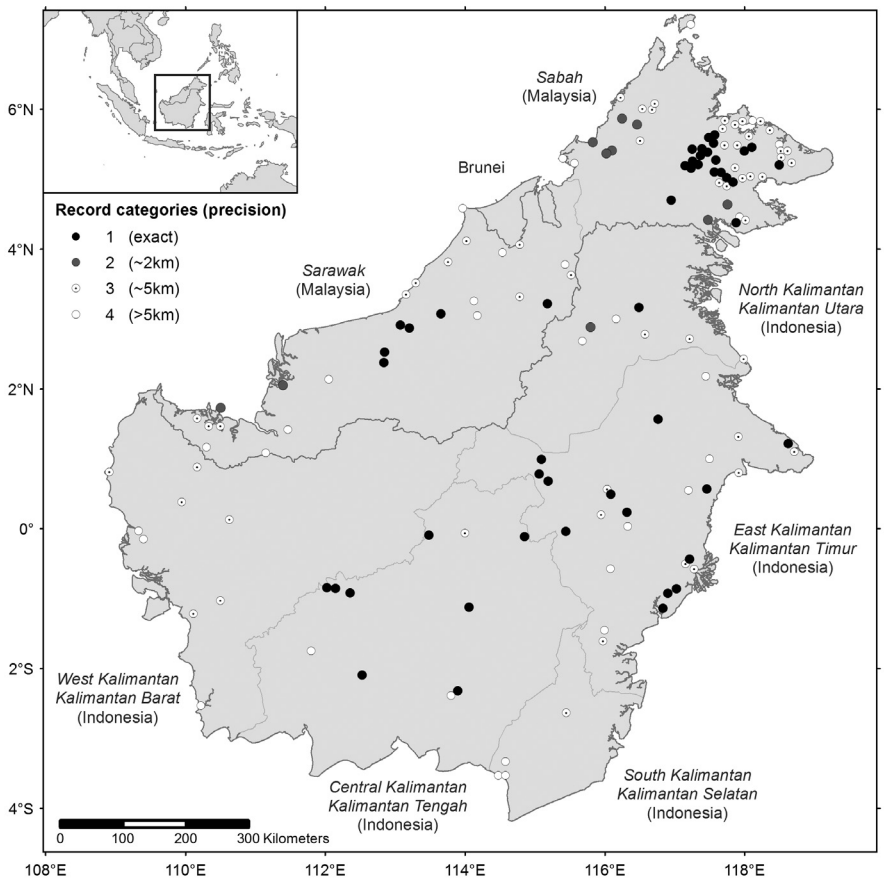

Fig. 2. Location of common palm civet *Paradoxurus hermaphroditus* occurrence records across Borneo, showing categories of spatial precision as well as country and state boundaries.

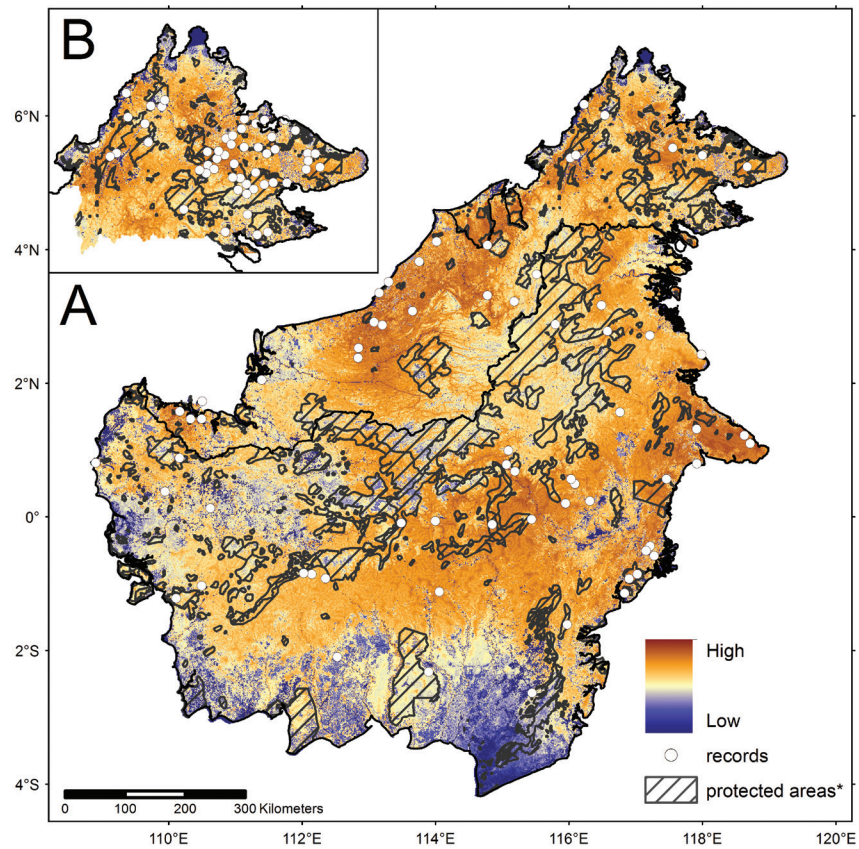

Fig. 3. Predictive Habitat Suitability Index (HSI) models for common palm civet *Paradoxurus hermaphroditus* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al. (2016).

the north and the Sungai Mahakam in the south, and areas around Semayang and Melintang lakes.

West Kalimantan, Indonesia. Most areas of West Kalimantan were predicted to be moderately to less suitable. There were no records from the eastern part of this province; it remains unclear whether this indicates lower occurrence or limited survey effort. As with South Kalimantan, the relatively low search effort in this province may have produced a biased low estimate of habitat suitability in this region. More surveys could give a reliable picture of its status in West Kalimantan.

Conservation threats and necessary action. The large proportion of Borneo predicted to be suitable habitat for the common palm civet includes anthropogenic areas such as plantations, and indicates there should be no concerns over limited habitat availability for this species. Previous studies on Borneo suggested that common palm civet can adapt well to habitat encroachment and tolerates some level of human disturbance (e.g., Stuebing & Gasis, 1989; Yasuma & Andau, 2000; Meijaard et al., 2008; Rustam et al., 2012; Nakabayashi et al., 2014). However, this does not ensure that this species needs no conservation actions. Although there is no evidence that immediate conservation actions are required, the situation could change because this species is increasingly captured as a pet or for the production of civet coffee, compounding longstanding widespread killing as a pest or for meat (Shepherd, 2012; D'Cruze et al., 2014; M Nakabayashi, pers. obs.). Further research should focus on evaluating the population-level impacts of these threats. Further, whatever the internal taxonomy of common palm civet, the civet coffee trade is likely to pose an additional conservation threat through long-distance transport and the mixing of lineages. Long-term research on the ecology and population status of this species would allow a better understanding of the potential threats and precise habitat needs for this species but is, among the Bornean carnivores, a low priority, given the number of other species that are more imminently threatened.

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