

Predicted distribution of the masked palm civet *Paguma larvata* (Mammalia: Carnivora: Viverridae) on Borneo

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

Abstract. The masked palm civet *Paguma larvata* is a small carnivore within the civet family Viverridae, currently listed as Least Concern on The IUCN Red List of Threatened Species. Across its global range the masked palm civet uses a range of habitats in tropical and subtropical regions, from lowlands to highlands, but its exact ecological requirements and the use of modified habitat remains unclear. We analysed 49 (Balanced Model) and 72 (Spatial Filtering Model) location records of the masked palm civet from Borneo to predict habitat suitability. The resulting model predicted the interior and high elevation areas of Borneo to be suitable habitat, while the coastal and other low-lying areas, such as the extensive peat swamp forests in Central Kalimantan, were predicted to be unsuitable. Greater survey effort in South, Central and West Kalimantan and in Brunei is necessary to obtain more records to improve current models and understanding. The species is probably widespread in Borneo and its likely stronghold is in the higher-elevation forests which are currently less threatened and for a large part protected. Thus, species-specific conservation efforts are not considered warranted at this time.

Key words. Masked palm civet, *Paguma larvata*, Borneo, distribution, habitat suitability

Abstrak (Bahasa Indonesia). Musang Galing *Paguma larvata* merupakan karnivor berukuran kecil dalam keluarga musang. Saat ini berstatus Resiko Rendah dalam daftar IUCN Red List of Threatened Species. Mengikuti persebaran alamnya, musang Galing dijumpai pada berbagai tipe habitat dari mulai wilayah tropika hingga sub-tropika dan dari dataran rendah hingga dataran tinggi; namun bagaimana kebutuhan ekologisnya secara pasti serta kemampuan penggunaan habitat yang termodifikasi masih belum jelas. Untuk lebih memahami kebutuhan habitatnya, kami menganalisa 49 (Model Penyeimbang) dan 72 (Model Spasial Tersaring) catatan keberadaan musang Galing di Borneo untuk memperkirakan kesesuaian habitatnya. Hasil pendugaan pemodelan menunjukkan bagian pedalaman dan wilayah elevasi tinggi di Borneo merupakan habitat yang sesuai, dimana wilayah pesisir dan dataran yang rendah, seperti hutan rawa gambut di Kalimantan Tengah, merupakan wilayah yang tidak sesuai. Survey yang lebih mendalam untuk wilayah Kalimantan Selatan, Tengah dan Barat serta Brunei diperlukan guna penambahan data sehingga meningkatkan ketepatan pemodelan serta pemahaman. Jenis ini kemungkinan besar tersebar luas di Borneo and tampaknya terbanyak adalah pada daerah hutan berelevasi tinggi, dimana saat ini berada pada posisi kurang terancam dan pada banyak wilayah merupakan wilayah perlindungan. Untuk itu upaya konservasi yang mengkhususkan pada satwanya saat ini belum diperlukan.

Abstrak (Bahasa Malaysia). Musang Lamri *Paguma larvata* adalah sejenis karnivora kecil dari keluarga musang. Ia disenaraikan di dalam Senarai Merah Spesies Terancam IUCN sebagai Kurang Membimbangkan. Spesies ini tersebar luas di dunia dan boleh dijumpai di pelbagai jenis habitat dari kawasan tropika hingga sub-tropika dan dari kawasan tanah rendah hingga tanah tinggi. Namun, keperluan ekologi yang tepat dan sejauh mana ia mampu bertahan dalam habitat yang telah diganggu manusia, masih belum diketahui dengan jelas. Untuk memahami keperluan habitatnya dengan lebih mendalam, kami menganalisis 49 rekod (Model Seimbang) dan 72 rekod (Model yang ditapis secara spasial) untuk membina model kesesuaian habitat. Model yang dibina meramalkan kawasan pedalaman dan tanah tinggi di Borneo adalah habitat yang sesuai bagi spesies ini manakala kawasan pinggir lautan dan kawasan tanah rendah yang lain seperti hutan rawa gambut yang meluas di Kalimantan Tengah, diramalkan tidak sesuai. Pemantauan yang lebih meluas perlu dilakukan di Kalimantan Selatan, Tengah dan Barat, serta di Brunei untuk mendapatkan lebih banyak rekod supaya dapat mempertingkatkan model yang sedia ada dan pemahaman tentang spesies ini. Spesies ini mungkin bertaburan luas di Borneo, terutamanya di kawasan tanah tinggi yang kurang terancam dan banyak terdiri daripada kawasan terlindung. Oleh demikian, tiada sebarang tindakan pemuliharaan yang khas diperlukan untuk spesies ini pada masa ini.

INTRODUCTION

The masked palm civet *Paguma larvata* (C.E.H. Smith, 1827), is a small carnivore within the civet family Viverridae found almost throughout South-east Asia and further west through the Himalayan foothills and north through large parts of China; it has been introduced to Japan (Duckworth et al., 2008). Its coat is a solid dark to reddish-brown depending on the geographic area, the lower legs are generally darker than the body and the tip of the tail is often white (Davis, 1962). The characteristic white markings on the face vary with geographic region: individuals from much of mainland South-east Asia have a broad white stripe down the middle of the forehead and muzzle, with a white spot beneath the eyes (Blanford, 1885; Lydekker, 1896), whereas individuals from Borneo (Fig. 1A) have a whitish face (Payne et al., 1998). The diet of the masked palm civet is varied and consists of fruit, small mammals, birds, amphibians, reptiles, snails, crabs and insects (Zhou et al., 2008). It is mainly nocturnal; Ho (2009), for example, found its activity to peak between 0200 and 0600 hours and ground-level camera-trap data from Borneo suggest a similar pattern (Ross et al., in press). It is also tolerant to some degree of habitat alteration; where no hunting occurs, it has been found to use almost entirely unnatural habitat in parts of its range (Zhou et al., 2008; Ho, 2009). As such, it is perhaps less threatened by habitat alteration than are sympatric small carnivores, although a comparison of survival probabilities has not been possible. The masked palm civet has been specifically studied in China, where it was found in coniferous, broad-leaved and bamboo forest and woodland–agricultural mosaic over a wide elevation range of 560–2250 m a.s.l. (Zhou et al., 2008). In Taiwan, Chen et al. (2009) found the masked palm civet to be associated with both secondary forest and areas with good canopy cover. It is not clear whether this degree of habitat flexibility characterises the species throughout its range.

Medway (1977) traced Bornean records only from the northern half of the island. The southernmost Bornean records available to him came from Kuching; Gunung [=Mount] Kenepai and Gunung Liang Kubung in the upper Sungai [=River] Kapuas; and Long Petai in the upper Sungai Mahakam. Payne et al. (1998) traced no records from further south. Medway's (1977) speculation that northern restriction might prove to be spurious can now be shown to be so. A specimen (skin and skull) collected by J. Gale at Kemawen, in the upper Barito, Kalimantan (about 1°07'S, 114°54'E), in 1969 is held at Museum Zoologicum Bogoriense, Cibinong, Bogor, Indonesia; GS, JR and J. W. Duckworth all examined the specimen or photographs of it, and concur with the

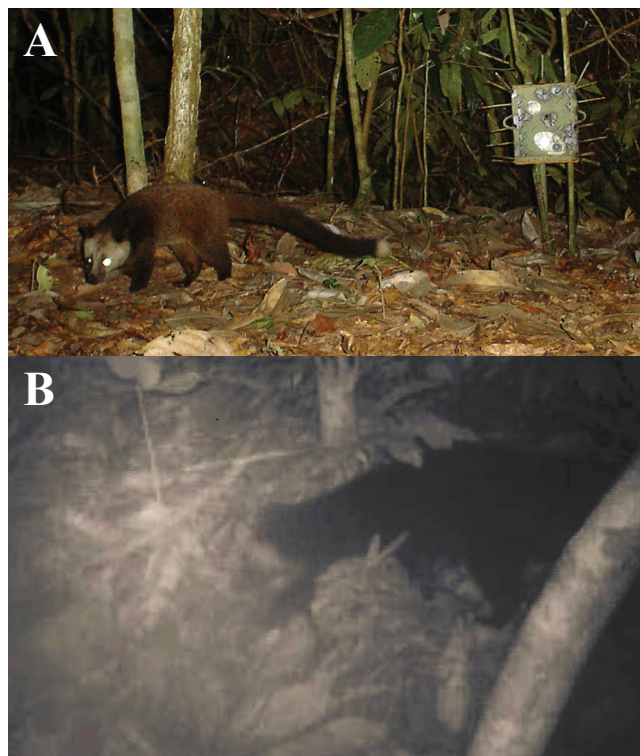


Fig. 1. A, masked palm civet *Paguma larvata* camera-trapped in Danum Valley Conservation Area, Sabah, Malaysia, on 6 February 2008 (photograph: Joanna Ross and Andrew Hearn). B, masked palm civet *Paguma larvata* camera-trapped in the Schwaner mountains, in PT. Sari Bumi Kusuma concession area, N 0°51'30" E 112°08'59", 217 m asl, on 16 May 2012 (Photograph by: Hiromitsu Samejima & Gono Semiadi).

identification. It was camera-trapped at similar latitude in the Schwaner mountains in 2010–2011 (Samejima & Semiadi, 2012; Fig. 1B). There are also two direct sightings (from nocturnal spotlighting in 1996–1997; from somewhat further south at about 1°13'S), at Cabang Panti Research Station, Gunung Palung National Park, West Kalimantan, Indonesia in 1996–1997 (AJM pers. obs.).

Across Borneo it has been recorded in primary forest (Matsubayashi et al., 2011; Ross et al., in press), logged forest (Mathai et al., 2010), forest fragmented because of logging activities (Samejima & Semiadi, 2012), and regenerating burnt forest areas (Rustam et al., 2012). However, a number of surveys undertaken in 2007–2009 in West Kalimantan detected only few masked palm civets in those patches of good quality forests remaining in logging concessions and the protected forest of Bukit Perai. One individual was sighted in a secondary forest along 5.7 km of transect lines observed over three days, whilst three were sighted in both little degraded and secondary forests of logging concession areas during a 14-day observation over about 15 km of transect lines (A. Adhikerana, pers. comm.). Its use of agricultural plantations on Borneo remains unclear. There is evidence that the presence of fruiting trees (Wang, 1987 in Zhou et al., 2008) and possibly mineral licks (Matsubayashi et al., 2007) are important for the masked palm civet. Evidence also suggests the species plays an important role in forest regeneration through seed dispersal (Zhou, 2010).

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In some areas of Borneo, the species is hunted opportunistically (Murphy, 2007) and a few are occasionally sold as pets on the black market in Jakarta, Java (to which island the species is not native), Indonesia (1–2 animals every 2–3 months; G Semiadi, pers. data). During five years of surveillance in Sumatra, only nine individuals were noted in markets (Shepherd, 2008). In Indonesia, the masked palm civet can be legally targeted by licensed professional hunters of PERBAKIN (the Indonesian National Rifle Association) under a Ministry of Forestry Regulation (MoF, 2010) although available data suggest that the species has never been specifically targeted (G Semiadi, pers. data).

Currently the species is listed as Least Concern on The IUCN Red List of Threatened Species reflecting its wide geographic distribution and presumed large population. However, it is thought that the population might be declining (Duckworth et al., 2008). Within Borneo, the masked palm civet is included on Schedule 2 of the Sabah's Wildlife Conservation Enactment, meaning a limited number of individuals can be hunted. A similar level of protection is afforded in Sarawak where the masked palm civet is listed as Protected under Part II of the First Schedule of the Wildlife Protection Ordinance. However, the species is neither listed under Brunei's Wildlife Protection Act nor under Indonesia's Government Regulation No. 7/1999.

RESULTS

Species occurrence records. Of 143 location records obtained for the masked palm civet, 60 were recent (2001–2011) (Fig. 2; Table 1). After removing 44 records because of spatial imprecision (greater than 5 km) the model used 49 (Balanced Model) and 72 (Spatial Filtering Model) records to predict habitat suitability (see Kramer-Schadt et al., 2016). Records were obtained from across Borneo although, plausibly because of the greater survey effort, there were proportionately more records from Sabah than from elsewhere, with only few records from Central Kalimantan. We did not find any spatially precise records from Brunei nor from South Kalimantan, although Bennett (2014) recorded the species at Ulu Temburong National Park, Brunei.

Habitat associations. We used the opinions of 10 respondents to assess the suitability of different land-cover classes for the masked palm civet (Table 2). Lowland, upland and lower montane forest were considered the most suitable habitats for this species, while young plantations and crops, bare areas, burnt forest areas and water bodies were considered to be of low suitability. There was, however, little consistency among respondents to the questionnaire, with the ranking for some habitats (e.g., lower and upper montane forest) ranging from 0 (unsuitable) to 4 (very good).

Habitat suitability index (HSI) model. The model predicts that the central areas of Borneo are the most suitable for the masked palm civet, with the lower elevation and coastal areas being unsuitable (Fig. 3). Most of Sabah, Sarawak, Brunei and East and North Kalimantan were predicted to be suitable habitat, whereas most of South, Central and West Kalimantan

were predicted to be unsuitable. The mapped predictions of the habitat suitability index model in Fig. 3 need to be interpreted with caution (see Kramer-Schadt et al. (2016) for more details). Of note, some areas, particularly in South and West Kalimantan, had little information, reflecting the lower survey efforts in these areas. Although search-effort bias has been minimised during the modelling, these areas might still be underrepresented in the distribution map especially if they are climatically distinct from the rest of Borneo. This is particularly likely for South Kalimantan which has a more pronounced dry season (see Kramer-Schadt et al., 2016: Fig. 3A). Thus, unless there are records sufficiently spatially precise to have been used in the model, the prediction cannot accurately reflect the potential for occurrence in that region. In general, only further surveys could determine if the lower predictions are because of the minimal survey efforts or reflect a genuine lower suitability of these areas for the species, perhaps because of different climatic conditions or because large areas have been transformed to unsuitable land-cover (see Kramer-Schadt et al., 2016: Fig. 3B).

DISCUSSION

Habitat suitability. Despite being listed as Least Concern on The IUCN Red List of Threatened Species, the masked palm civet remains a poorly studied and little-understood species in Borneo, at least. The current habitat suitability modelling has provided testable hypotheses regarding the habitat requirements for the masked palm civet and provides a platform for further research. The use of respondents' opinions to assess habitat suitability of land-cover classes has some drawbacks, because of the speculation involved, reflected by the broad range of values for some of the land-cover classes assessed. This in turn reduces the precision of the final model and may produce spurious patterns, particularly for inconsistently scored land-cover classes. In particular, Belden et al. (2014) drew attention to the paucity of verifiable records from lowland Borneo (below 300 m or so) far from extensive or high hills. That said, our results suggest a fairly large proportion of Borneo is suitable habitat for the masked palm civet.

Sabah, Malaysia. The majority of Sabah is predicted to provide suitable habitat for the masked palm civet, the notable exceptions being the unprotected, low-lying coastal areas and extensive oil palm plantations in the east of the state. An important area for wildlife conservation in eastern Sabah is Tabin Wildlife Reserve where the masked palm civet has recently been camera-trapped (Ross et al., in press). The interior of Sabah retains good forest cover: this mosaic of totally protected areas connected by commercial forest reserves includes the Danum Valley, Maliau Basin and Imbak Canyon Conservation Areas. This whole region is predicted to be highly suitable for the species. Crocker Range Park and Tawau Hills Park are also predicted to be highly suitable habitat and there are recent camera-trap records of the species from all these areas (Brodie & Giordano, 2011; Matsubayashi et al., 2011; Ross et al., in press). The trans-boundary areas between Sabah and North Kalimantan and also Sabah and Sarawak, along which there are no totally

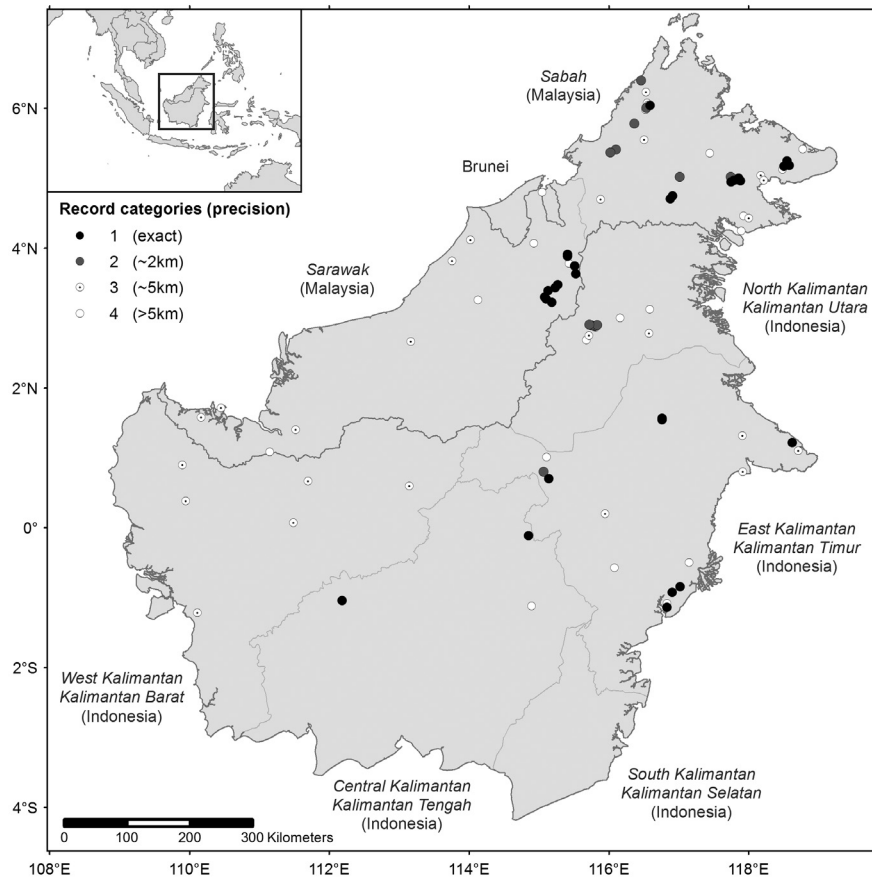


Fig. 2. Location of masked palm civet *Paguma larvata* occurrence records across Borneo, showing categories of spatial precision as well as country and state boundaries.

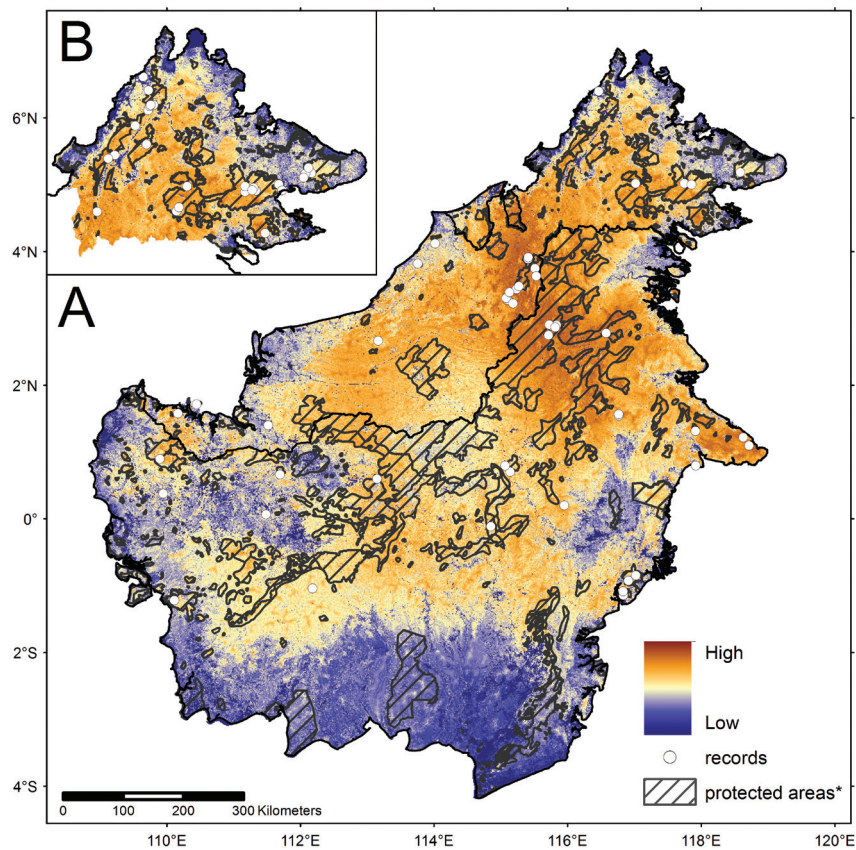


Fig. 3. Predictive Habitat Suitability Index (HSI) models for the masked palm civet *Paguma larvata*, including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al.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

Table 1. Summary of the occurrence records for the masked palm civet *Paguma larvata* 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	35	21	29	33
Category 2 500 m – 2 km	17	8	12	14
Category 3 2–5 km	47	20	31	6
Category 4 above 5 km	23	--	--	4
Category 5 (no coordinates*)	21	--	--	3
Total	143	49	72	60

M₁ = Balanced Model; M₂ = Spatial Filtering Model (2 km); *only coarse location description was available.

Table 2. Land-cover reclassification for the masked palm civet *Paguma larvata* based on the questionnaire results of 10 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.13	1–4
Upland forest	3.44	2–4
Lower montane forest	3.00	0–4
Upper montane forest	2.25	0–4
Forest mosaics/lowland forest	2.75	*
Forest mosaics/upland forest	2.89	#
Swamp forest	2.00	0–4
Mangrove	0.86	0–4
Old plantations	2.43	0–4
Young plantations and crops	1.43	0–4
Burnt forest area	1.00	0–3
Mixed crops	1.14	0–3
Bare area	0.00	0–0
Water and fishponds	0.13	0–1
Water	0.00	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).

protected areas (Paya Maga Forest Reserves continuous with Sipitang and Ulu Padas forest reserves) are also predicted to be very suitable.

Sarawak, Malaysia. Much of Sarawak is predicted to offer suitable habitat for the masked palm civet, especially the higher elevation eastern part of the state where it borders Sabah and North Kalimantan and also Gunung Mulu National Park. The coastal areas and western part are predicted to be unsuitable. There is a paucity of records from the totally protected areas of Sarawak, with the exception of Pulong Tau National Park. However, this might reflect survey bias rather than being indicative of the true distribution. There are also records from a logging concession to the south of Pulong Tau National Park, where the species was detected

in both logged and unlogged forest (Mathai et al., 2010) and Anap-Muput forest management unit in central Sarawak (H. Samejima & J. Hon, unpubl. data).

Brunei Darussalam. Although the model used no records from Brunei, more than half the country is predicted to be suitable habitat for this species, although, akin to the rest of Borneo, coastal areas are predicted to be unsuitable. Potentially important areas in Brunei are Ulu Temburong National Park and Labi Hills Protection Forest, which form a trans-border protected complex with Gunung Mulu National Park in Sarawak. The paucity of records from Brunei is possibly because of low survey effort: further surveys could ascertain the true status of the species in the country.

East Kalimantan, Indonesia. A large proportion of East Kalimantan is predicted to be suitable for the masked palm civet, especially the interior areas. An interesting area of East Kalimantan is the Mangkaliat peninsula, north of Kutai National Park, where Sangkulirang Karst Nature Reserve is situated. There are recent records from Bukit Soeharto Grand Forest Park (Rustam et al., 2012), and unlike the other coastal areas of Borneo, most of the Mangkaliat peninsula is predicted to be suitable habitat for the species.

North Kalimantan, Indonesia. There is a cluster of recent records from Kayan Mentarang National Park which is almost contiguous with Pulong Tau National Park in Sarawak (Augeri, 2005). These two protected areas and the interconnecting production forest form a potentially important transborder area for the masked palm civet.

South Kalimantan, Indonesia. Our models predict that most of South Kalimantan is unsuitable habitat for the masked palm civet, possibly because we received only one record, moreover a spatially imprecise one, from the province, or because of different climatic conditions (see comment above). This record was from near Banjarmasin: because this is a port city, it is possible this record stems from a traded individual. South Kalimantan is under-surveyed relative to other areas of Borneo, so more studies are necessary to ascertain the suitability of the province for the species.

Central Kalimantan, Indonesia. The majority of Central Kalimantan was predicted to be unsuitable for the masked palm civet. The south of Central Kalimantan is dominated by extensive peat swamp forests in which Cheyne et al. (2010) did not detect this species despite a survey effort of over 6000 camera-trap-nights. The higher elevation habitat in the north of this province is predicted to be better for the species, and Samejima & Semiadi (2012) recorded it in Schwaner mountains. Further surveys in this area are warranted.

West Kalimantan, Indonesia. Very little of West Kalimantan was predicted to be suitable for the masked palm civet. The records we received from this province were few, imprecise and mostly from protected areas. The Bukit Batutenobang Protection Forest and Betung Kerihun National Park may be key areas in this province reflecting their higher-elevation interior forest and connectivity with protected areas in Central Kalimantan and Sarawak.

General conclusions. The masked palm civet appears to have a fairly wide distribution across a range of habitats on Borneo, demonstrating habitat plasticity. However, on Borneo, it does appear to be forest dependent and to be more strongly associated with higher elevations than the lowlands. If this suggested elevation selection is true, the masked palm civet may be affected less by habitat alteration than are species strongly associated with the lowlands, given the more rapid modification of low-elevation forest on Borneo than of that in upland areas. Recent records from production forest are promising and suggest this species is tolerant, at least to some degree, to habitat alteration. These commercial forests

may serve as corridors between otherwise isolated fragments of good forest habitat. The exact ecological requirements of the masked palm civet on Borneo remain poorly understood and the species will benefit from targeted research to clarify its use of modified habitats and the extent of its reliance on different types of forests. It is also important to gain a clearer picture of its use of low-lying areas (below about 300 m, particularly those far from mountainous areas; Belden et al., 2014) and also where the southern edge of its range lies. Records from further south than the southernmost specimen here traced (1°07'S) warrant explicit publication: as discussed by Wilting et al. (2010) and Belden et al. (2014), claimed sight-records of the masked palm civet on Borneo might sometimes be in error for common palm civets *Paradoxurus hermaphroditus* (Pallas) with relatively plain body pattern and a white tail-tip.

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