

## Predicted distribution of the collared mongoose *Herpestes semitorquatus* (Mammalia: Carnivora: Herpestidae) on Borneo

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

**Abstract.** Collared mongoose *Herpestes semitorquatus* is known to inhabit Borneo, Sumatra and possibly the Philippines. It occurs widely in Borneo, possibly with the exception of South Kalimantan. It is very likely to occur in Brunei, although no explicit records have been traced. The pelage is typically brown or reddish-brown, with a few strongly reddish-orange individuals recorded in Sabah. It has never been studied in the field, so information on its ecology is limited. We used MaxEnt niche distribution modelling to predict the current distribution of collared mongoose in Borneo. We collected a total of 117 occurrence records from all regions, except Brunei and South Kalimantan. To reduce possible negative effects of uneven search-effort, 27 records were used in the Balanced Model and 77 in the Spatial Filtering Model to map habitat suitability. Our habitat suitability index model predicted that a large proportion of Borneo, mostly the lowland and upland forests in the interior encompassing large blocks of both national and transboundary protected area networks, is suitable for collared mongoose. Increased survey effort is warranted in areas predicted to be suitable but lack data, such as northern Central Kalimantan, central East Kalimantan, South Kalimantan and south-central Sarawak. To understand the effects of logging on collared mongoose, further investigations are required.

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

**Abstrak (Bahasa Indonesia).** Garangan Ekor-Panjang *Herpestes semitorquatus* diketahui mendiami wilayah Borneo, Sumatera dan kemungkinan Filipina. Mereka tersebar luas di Borneo, terkecuali kemungkinan tidak untuk Kalimantan Selatan. Hampir dipastikan jenis ini juga terdapat di Brunei, walau catatan resmi belum diperoleh. Rambut malai berwarna khas coklat atau coklat kemerahan, dengan beberapa individu berwarna oranye kemerahan untuk wilayah Sabah. Jenis ini belum diteliti secara seksama sehingga informasi aspek ekologi sangat diperlukan. Kami menggunakan pendekatan pemodelan persebaran wilayah MaxEnt untuk menduga persebaran saat ini dari Garangan Ekor-Panjang di Borneo. Kami mengumpulkan 117 catatan perjumpaan dari semua wilayah, terkecuali Brunei dan Kalimantan Selatan yang tidak ada datanya. Untuk menekan kemungkinan adanya pengaruh negatif dari pencarian yang tidak merata, hanya 27 catatan yang dipakai dalam model penyeimbang dan 77 dalam pemodelan spasial tersaring dalam memetakan kesesuaian habitat. Hasil index model kesesuaian habitat memperkirakan sebagian besar wilayah Borneo, umumnya terpusat pada wilayah dataran rendah dan hutan dataran tinggi di wilayah pedalaman yang merupakan wilayah luas dari hutan di dua negara dan wilayah antarbatas, sesuai untuk Garangan Ekor-Panjang. Kami menekankan perlunya peningkatan survey di wilayah yang diperkirakan sesuai namun datanya kurang, seperti di bagian utara Kalimantan Tengah, daerah tengah Kalimantan Timur, Kalimantan Selatan dan bagian tengah selatan Sarawak. Namun untuk memahami pengaruh dari penebangan hutan terhadap Garangan Ekor-Panjang, penelitian lebih lanjut masih diperlukan.

**Abstrak (Bahasa Malaysia).** Bambun/Garangan Ekor Panjang *Herpestes semitorquatus* dikenal pasti wujud di Borneo, Sumatra dan kemungkinan juga di Kepulauan Filipina. Ia tersebar secara meluas di Borneo, kecuali Kalimantan Selatan. Ia mungkin juga terdapat di Brunei, walaupun tiada rekod sahih dapat dikesan. Kebiasaannya, bulu Bambun Ekor Panjang berwarna perang atau merah-keperangan, dan terdapat beberapa rekod individu yang ditemui di Sabah berwarna merah-jingga. Ia belum pernah dikaji di lapangan, maka lebih banyak maklumat berkaitan ekologi diperlukan. Kami menggunakan pendekatan Model Taburan Ceruk MaxEnt untuk meramal taburan terkini Bambun Ekor Panjang di Borneo. Kami telah mengumpulkan 117 rekod daripada seluruh bahagian Borneo, kecuali Brunei dan Kalimantan Selatan yang tidak mempunyai sebarang rekod. Untuk mengurangkan kesan negatif akibat usaha pencarian yang tidak seragam, 27 rekod digunakan dalam model seimbang dan 77 rekod di dalam model yang ditapis secara spasial, untuk memetakan kesesuaian habitat. Model kesesuaian habitat indeks kami meramalkan sebahagian besar Borneo, terutamanya di kawasan hutan tanah rendah dan tanah tinggi di pedalaman, yang terdiri daripada rangkaian kawasan perlindungan negara dan trans-sempadan, adalah sesuai untuk Bambun Ekor Panjang. Kami menekankan keperluan untuk mempertingkatkan usaha pemantauan di kawasan yang diramal sesuai tetapi kekurangan data, seperti di bahagian utara Kalimantan Tengah, bahagian tengah Kalimantan Timur dan bahagian tengah selatan Sarawak. Namun begitu, untuk memahami kesan pembalakan ke atas Bambun Ekor Panjang serta kadar toleransinya terhadap gangguan hasil pembalakan, penyelidikan yang lebih lanjut perlu dilakukan.

## INTRODUCTION

Mongoose are small-bodied carnivores of the family Herpestidae. Of the 33 species from 14 genera worldwide, only one genus, *Herpestes* Illiger, occurs in Asia, of which two species, collared mongoose *H. semitorquatus* Gray, and short-tailed mongoose *H. brachyurus* Gray, inhabit Borneo (Corbet & Hill, 1992). Payne et al. (1985) recognised a third species in Borneo, Hose's mongoose *H. hosei* Jentink, but Corbet & Hill (1992) considered it conspecific with *H. brachyurus*.

It can be difficult to distinguish between *H. brachyurus* and *H. semitorquatus* (Fig. 1) in the field when the neck-stripe of *H. semitorquatus* is not clearly visible; the longer tail of *H. semitorquatus* is a key feature to check. *Herpestes semitorquatus* loosely resembles yellow-throated marten *Martes flavigula* (Boddaert), in camera-trap images. *Martes flavigula* has a yellowish chest and throat, a much longer tail, a rounded muzzle and, usually, a drooping tail. The pelage of *H. semitorquatus* on Borneo is typically brown or reddish-brown, but individuals with a strongly reddish-orange coloration have been recorded in Sabah and Sumatra, albeit rarely, which may lead to confusion with the Malay weasel *Mustela nudipes* Desmarest (Ross et al., 2012).

Collared mongoose has been recorded in Borneo at various localities, in Sabah in the Sandakan region, Kalabakan and south-western Sabah (Payne et al., 1985), Maliau Basin, Danum Valley, Sukau and the west coast opposite Labuan (Yasuma & Andau, 2000), Deramakot Forest Reserve (Wilting et al., 2010), Tangkulap Forest Reserve and Segaliud Lokan Forest Reserve (A Wilting & A Mohamed, unpubl. data), near Poring hot springs (Wells et al., 2005), Ulu Segama Forest Reserve (Ross et al., in press); in most parts of Sarawak (Payne et al., 1985) including the upper Baram (Mathai et al., 2010), Samarakan (Belden et al., 2007) and Anap Muput Forest Management Unit (J Hon, unpubl. data.); in scattered but widely spread localities in Kalimantan (Corbet & Hill, 1992), where exact locality records are scarce, as far south as Sabangau peat swamp forest (Cheyne et al., 2010). The species presumably occurs in Brunei although no explicit records have been traced.

Collared mongoose is mainly ground-dwelling, and has been recorded at various elevations ranging from 10 m (Cheyne et al., 2010) to 600 m a.s.l. (Wells et al., 2005), with a historical record from Gunung [=Mount] Dulit at 4000 ft [1220 m a.s.l.] (Davis, 1958), and more recently, one from Crocker Range National Park at 1452 m a.s.l. (AJ Hearn, J Ross & DW Macdonald, unpubl. data). In Sumatra, the only other landmass on which the species has



Fig. 1. Collared mongoose *Herpestes semitorquatus* camera-trapped in Deramakot Forest Reserve, Sabah, Malaysia on 12 August 2008. (Photograph by: A. Wilting & A. Mohamed/IZW & SFD)

been conventionally accepted to occur, published records are few (Holden & Meijaard, 2012; Pusparini & Sibarani 2014). Veron et al. (2015) considered that the Philippine populations of mongooses, formerly generally accepted to be short-tailed mongoose, were closer to collared mongoose and that the Palawan mongooses should be included in this species. Further research with more specimens from Palawan is warranted.

Collared mongoose has been recorded in a wide range of habitats, including primary and logged lowland mixed dipterocarp forests (Wells et al., 2005; Mathai et al., 2010; Wilting et al., 2010; Ross et al., 2012, in press); peat swamp forest (Cheyne et al., 2010); mixed secondary-acacia forest mosaics (Belden et al., 2007); and mixed mature albizia-cacao plantation (Stuebing & Gasis, 1989). It has been recorded within mature oil palm plantations (Ross et al., 2012, in press). Its diet includes small animals (Payne et al., 1985) including ants, with grass also ingested (Davis, 1958). It appears more active by daylight (Payne et al., 1985); camera-trap data present a mixed picture, with one study of multiple sites in Sabah showing a strongly diurnal activity cycle (Ross et al., in press), a survey in a Indonesian peat-swamp forest showed peak activity during a period of 1–2 hours before noon and 2–3 hours after that (Cheyne et al., 2010), and Wilting et al. (2010) in Sabah recording the species active in the middle of the night. It is unclear if activity pattern varies regionally or is related to disturbance. Collared mongoose has not been studied in the field and thus information on its ecology is limited. It is listed as Data Deficient by The IUCN Red List of Threatened Species because the lack of information on its ecology hinders judgement of whether it is globally threatened by the current rate of forest conversion (Hon et al., 2008). There have not been any known incidences of trade of this species. It is protected under the Sarawak Wild Life Protection Ordinance 1998 and Sabah Wildlife Enactment 1997, but is not protected in Brunei or Indonesia.

## RESULTS AND DISCUSSION

**Species occurrence records.** In total, 117 records were collected (Fig. 2 & Table 1). Only records in Categories 1–3 of spatial precision were used for modelling. To reduce the search-effort bias, records were filtered resulting in 27 records (Balanced Model) and 77 records (Spatial Filtering Model) being used in the modelling exercise (see Kramer-Schadt et al. (2016) for methods).

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**Habitat associations.** The feedback received from the questionnaire, based on respondents' knowledge, suggests that collared mongoose prefers lowland and upland forests, and is least likely to occur in or near water bodies (Table 2). It is also likely to occur in lower montane forest, swamp forest and old plantations. There was general agreement between respondents that lowland forests are the best habitat. Almost all other land-cover classes had very little consistency across respondents, indicating how little is known about the species.

**Habitat suitability index (HSI) model.** The habitat suitability model (see Kramer-Schadt et al. (2016) for methods) predicted that a large proportion of Borneo, mostly the non-coastal region, is suitable for the collared mongoose (Fig. 3). Most of the peat-swamp areas are shown to be least suitable, although few of these areas have been surveyed and now many have been converted to other land uses, mostly oil palm plantation. Thus, 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). Some areas, particular 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).

In Borneo, the model predicted that current suitable habitat for collared mongoose is restricted to the lowland and upland forests in the interior (Fig. 3A). These areas are usually already opened up for logging activities. Locality records show that this species may occur amid some forms of logging, but the scale of tolerance is not known. It has been recorded even in recently logged sites (Wells et al., 2005; Samejima et al., 2012) but with no detail on how much non-logged forest remained close by, and if individuals could be wanderers from non-logged forests. Ross et al. (2012) recorded this species at several camera-trap stations in an oil palm plantation in Sabah, but the plantation bordered forest, and it remains unclear to what degree this species actually uses these plantations. There seem to be no records of collared mongoose from heavily settled areas, so it might have very little tolerance of human disturbance. There is little evidence to substantiate this assertion, largely because most people rarely report occurrences of 'common' species (amongst which mongooses are often placed). Very often, villagers report the presence of 'mongoose', but do not distinguish which species is actually preying on livestock and eggs, with some of them ending up being captured or killed.

**Brunei Darussalam.** Brunei's substantial forest cover has remained almost intact. Large parts of interior Brunei are predicted to contain suitable habitat. Large parts of the forests are connected to Sarawak. Ulu Temburong National Park and the forest catchment of the Sungai [=River] Ingei in the interior of Belait are predicted to be highly suitable. There are no major threats: small-scale illegal hunting is not targeted at collared mongoose.

**Sarawak, Malaysia.** Much of interior Sarawak is predicted to be suitable, where lowland and hill dipterocarp forests are distributed. The Pulong Tau Complex; Dulit; Tanjung Datu–Samunsam; Anap Muput; Batang Ai–Lanjak Entimau; and Hose–Laga–Usun Apau complex are predicted to be highly suitable. The coastal regions, mostly the original extent of peat swamp forests, are predicted to be less suitable; most have been converted to other land uses such as oil palm plantations. The greatest threat is forest conversion into monoculture plantations such as oil palm. This species seems to have a low tolerance for altered landscapes especially converted forests and human populated areas. The coastal plains and peat swamp forests might not now be of great conservation relevance for this species, because of ongoing large-scale conversion of such areas, mostly since the year 2000. Although there have been no records of collared mongoose from the coastal regions and peat swamps of Sarawak, this could result from surveys remaining limited here.

**Sabah, Malaysia.** Sabah holds the highest number of records. This perhaps results from the high concentration of wildlife researchers, both locally and from abroad, and the resulting high intensity of research. Nevertheless, the high number of records from Sabah might as well reflect a high concentration of collared mongooses there. The modelling exercise predicted almost the entire state, except the coastal regions with their large-scale oil palm plantations and settlements, to be suitable collared mongoose habitat. Conservation priority areas, such as Maliau Basin and Danum Valley Conservation Areas, are predicted to be highly suitable for collared mongoose. Other areas predicted to be suitable include Tabin Wildlife Reserve, Sipitang/Sungai Ulu Padas Forest Reserve, which is contiguous with the Paya Maga Forest Reserve in Sarawak, and the Crocker Range National Park which is contiguous with Gunung Lumaku Forest Reserve and Sipitang Forest Reserve, forming a massive complex with the Pulong Tau Complex in Sarawak and Ulu Temburong National Park in Brunei. This large block comprises a mosaic of lowland and upland forests.

**Kalimantan, Indonesia.** The five provinces in Kalimantan, Indonesia, cover approximately two-thirds of Borneo. Most of the area is unprotected, not properly managed and suffers from high risk of degradation, mainly driven by economic development pressures. Large parts of the upstream forest areas are still in relatively good condition. A large-scale road network called Trans Kalimantan is proposed to connect the northern East Kalimantan coast to West Kalimantan, cutting across the interior highlands, Kayan Mentarang National Park and connecting to the coast of Sarawak along the way. Such massive development will catalyse fragmentation of

Table 1. Summary of the occurrence records for collared mongoose *Herpestes semitorquatus* on Borneo.

Spatial Precision	Total No. of Records	No. of Records in M <sub>1</sub>	No. of Records in M <sub>2</sub>	No. of Recent Records 2001–2011
Category 1 below 500 m	75	15	57	75
Category 2 500 m – 2 km	6	1	4	1
Category 3 2–5 km	22	11	16	4
Category 4 above 5 km	10	-	-	1
Category 5 (no coordinates*)	10	-	-	1
<b>Total</b>	<b>117</b>	<b>27</b>	<b>77</b>	<b>81</b>

M<sub>1</sub> = Balanced Model; M<sub>2</sub> = Spatial Filtering Model (10 km); \*only coarse location description was available.

Table 2. Land-cover reclassification for collared mongoose *Herpestes semitorquatus* based on the questionnaire results of 11 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.45	3–4
Upland forest	3.00	1–4
Lower montane forest	2.00	1–4
Upper montane forest	0.71	0–2
Forest mosaics/lowland forest	2.43	*
Forest mosaics/upland forest	2.27	#
Swamp forest	1.38	0–4
Mangrove	0.88	0–3
Old plantations	1.71	0–3
Young plantations and crops	1.13	0–3
Burnt forest area	0.88	0–4
Mixed crops	0.63	0–2
Bare area	0.25	0–1
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).

current forested areas. Other large-scale threats include forest conversion for oil palm, drainage of peat swamp forests, illegal logging, mining, hunting, and to some extent, illegal wildlife trade.

**South Kalimantan, Indonesia.** With no confirmed record of collared mongoose from South Kalimantan, the model predicted little of this state to contain much suitable habitat: only the Meratus mountains are predicted to be moderately suitable. South Kalimantan has a more pronounced dry season, with climatic conditions very different from the rest of Borneo (extracted from Hijmans et al., 2005, 2015). To what extent the model prediction of low suitability is a result of a true absence of this species from the state or just

of the limited surveys from the state is uncertain. Systematic surveys in South Kalimantan would clarify this point.

**Central Kalimantan, Indonesia.** The interior lowland and hill areas are predicted to be highly suitable, including the Schwaner Range. Two large blocks of suitable priority conservation areas are the Sabangau National Park – Mungku Baru – Bawan forests, and the Bukit Baka – Bukit Raya National Park – Seruyan – Katingan – Bukit Perai – Bukit Rongga Forest Reserves. On the contrary, the coastal region is predicted to be less suitable; a large proportion is covered by peat swamp forests, as is Sabangau National Park, which is known to hold the species (Cheyne et al., 2010), and Mungku Baru – Bawan.

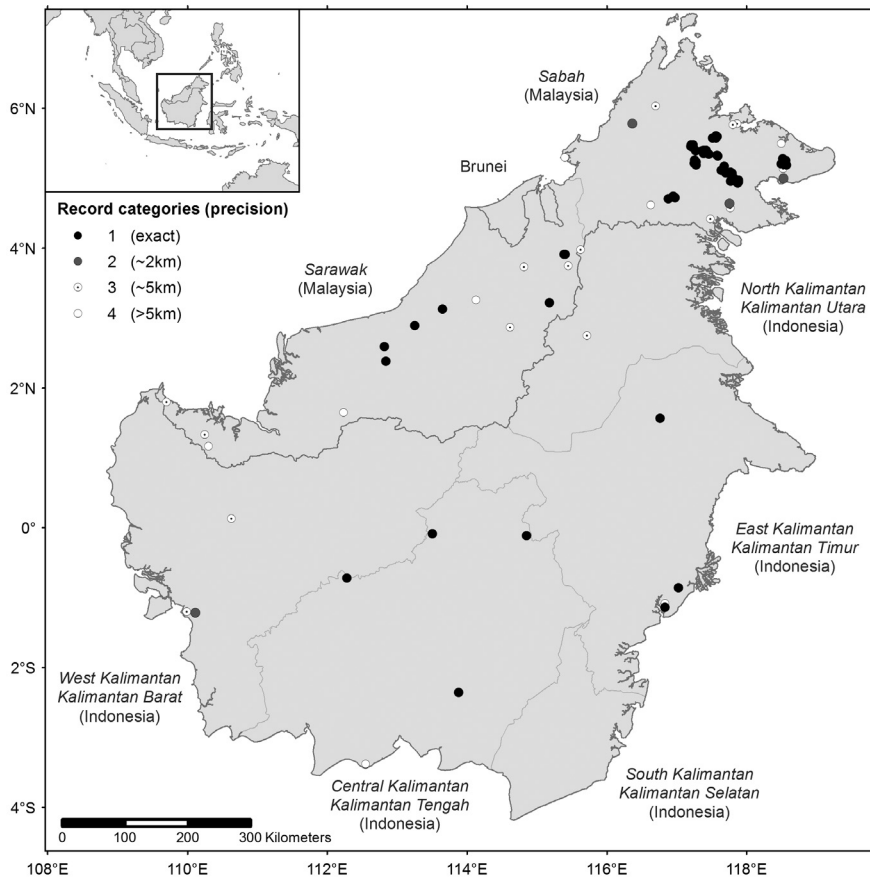


Fig. 2. Location of collared mongoose *Herpestes semitorquatus* occurrence records, showing categories of spatial precision as well as country and state boundaries.

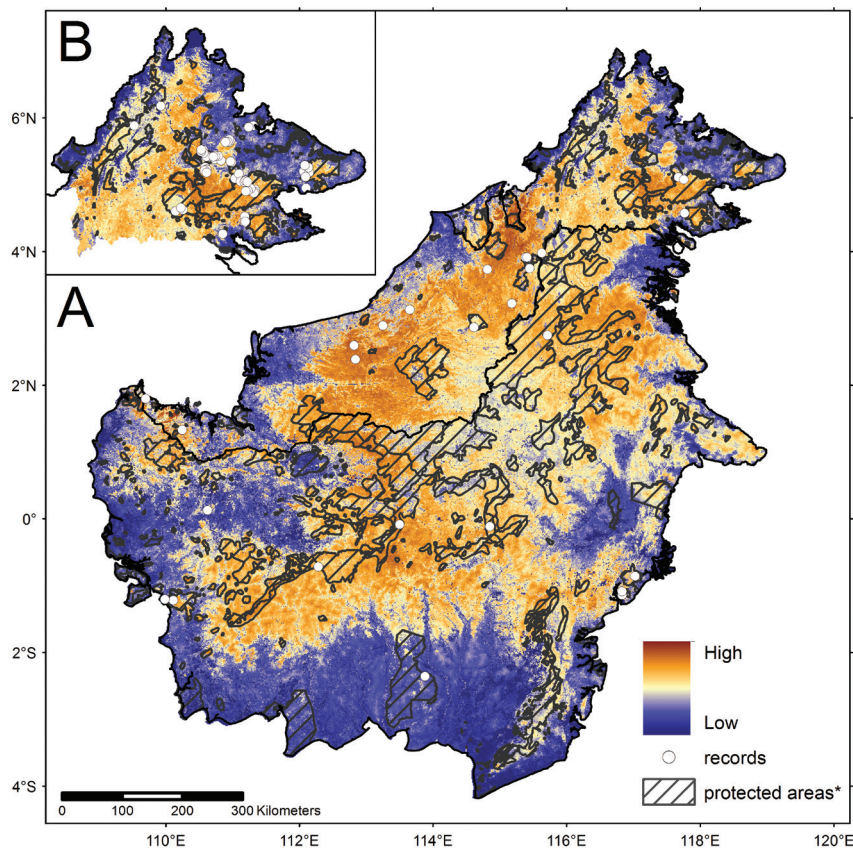


Fig. 3. Predictive Habitat Suitability Index (HSI) models for the collared mongoose *Herpestes semitorquatus* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt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

**West Kalimantan, Indonesia.** Two large blocks of priority conservation areas with high suitability are predicted. The Betung Kerihun National Park, of over 8000 km<sup>2</sup>, is rich in flora and fauna and connected to the Batang Ai – Lanjak Entimau complex in Sarawak. The Bukit Perai – Bukit Rongga protected forests are connected to the Bukit Baka – Bukit Raya National Park in central Kalimantan.

**North Kalimantan and East Kalimantan, Indonesia.** Much of the interior, comprising lowland and hill dipterocarp forests particular in North Kalimantan, is predicted to be suitable. The largest block of conservation priority area is the Kayan Mentarang National Park – Malinau Basin complex, which together with the Pulong Tau complex in Sarawak form an important large transboundary conservation area. This complex is predicted to be highly suitable for collared mongoose.

**Threats and conservation priorities.** Collared mongoose is widespread, albeit mostly sparsely recorded, in Borneo, with confirmed records from Sabah and Sarawak in Malaysia, and from all provinces except South Kalimantan in Indonesia. It presumably inhabits Brunei too. The paucity of confirmed records could be the result of limited surveys in these areas.

Survey efforts should be increased in areas predicted to be important habitat but so far lacking the data to support this, and in areas regarded as unsuitable, but currently lacking surveys to substantiate this prediction. Priority survey areas include northern Central Kalimantan; the southern half of North Kalimantan; South Kalimantan; and south-central Sarawak.

The habitat suitability modelling suggested that much of Borneo is potentially suitable for collared mongoose. These areas include large blocks of interior forests, comprising international transboundary sites which also include protected areas. Likewise, the relatively small number of records with detailed natural history information results in a low knowledge of habitat associations of collared mongoose. The habitat suitability model being partly based on respondents' opinions, this knowledge gap might affect the predictive model's accuracy, especially for peat swamp forests. Surveys could address the lack of information.

Also, the effects of logging on collared mongoose survival and distribution remain to be properly understood. Although the species has been recorded in selectively logged forests, the degree of its tolerance to disturbance from logging is not known. More detailed studies are needed.

Overall, since the last Red List assessment, for 2008 (Hon et al., 2008), a lot more information on the conservation status of collared mongoose has been generated, allowing a reassessment of its global status. Its wide distribution in a wide range of habitat types in Borneo, lack of indication that it is severely threatened, allows no particular conservation action to be suggested other than extensive retention of native forest. Addressing the scarcity of data on certain aspects of

its ecology would allow higher confidence that threats are not being overlooked.

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