

Predicted distribution of Hose's civet *Diplogale hosei* (Mammalia: Carnivora: Viverridae) on Borneo

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

Abstract. Hose's civet *Diplogale hosei* is one of the world's least known carnivores and is endemic to Borneo. We collected 43 records of which only 20 (Balanced Model) or 24 (Spatial Filtering Model) were used to model potential habitat suitability. We predicted habitat suitable for Hose's civet to be largely restricted to the central spine of the mountainous interior, corresponding to much of the northern half of the 'Heart of Borneo' complex. Although protected areas are scattered throughout this complex, many are poorly managed, facing threats from illegal logging and mining, poaching and encroachment. The surrounding matrix of logging concessions face conversion to monoculture plantations, in which there is no evidence that the species can persist. To ensure the conservation of the species, further research is urgently required, both in-depth ecological studies and basic inventory work using camera-traps across Borneo. More intensive surveys in all habitats are needed to improve current models so they can inform conservation planning more effectively. Pending sufficient information, sensible precautionary measures need to be taken such as increased enforcement including patrolling activities in key protected areas, encouraging sustainable forestry in the surrounding logging concessions and maintaining forested corridors to support movement and gene flow between sub-populations.

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

Abstrak (Bahasa Indonesia). Musang Gunung *Diplogale hosei* merupakan salah satu karnivora di dunia yang belum banyak dipahami dan endemik di Borneo. Kami telah mengumpulkan 43 catatan dimana hanya 20 (Model Penyeimbang) atau 24 (Model Spasial Tersaring) yang digunakan untuk pemodelan kesesuaian habitat yang potensial. Kami memperkirakan kesesuaian habitat untuk Musang Gunung sebagian besar berada terbatas di bagian tengah pedalaman pegunungan, mencakup sebagian utara wilayah "Heart of Borneo". Walaupun kawasan perlindungan cukup tersebar di wilayah tersebut, banyak pengelolaannya yang kurang memadai, menghadapi ancaman dari pembalakan dan penambangan liar, perburuan gelap dan penyerobotan lahan. Wilayah-wilayah di kawasan konsesi perusahaan hutan menghadapi ancaman dari konversi penanaman secara monokultur, dimana belum ada bukti jenis musang ini mampu bertahan hidup. Guna memastikan konservasi jenis musang ini, penelitian lebih lanjut sangat diperlukan, baik mengenai ekologi secara mendalam maupun pemantauan dasar menggunakan perangkat kamera di wilayah Borneo. Survey yang lebih intensif pada semua bentuk habitat juga diperlukan guna meningkatkan pemodelan yang telah ada, sehingga dapat memberikan informasi yang lebih baik berkaitan dengan perencanaan konservasi. Dalam keterbatasan informasi yang ada, langkah-langkah lebih lanjut diperlukan seperti penegakan hukum dan aktifitas patroli pada wilayah perlindungan utama, menyarankan pemanfaatan hutan secara berkelanjutan disekitaran wilayah konsesi perusahaan hutan dan menjaga koridor berhutan guna mendukung pergerakan dan laju genetik diantara sub-populasi.

Abstrak (Bahasa Malaysia). Musang Hitam Pudar *Diplogale hosei* adalah antara mammalia karnivora yang paling tidak diketahui di dunia. Ianya endemik (hanya didapati) di Borneo. Kami berkumpul 43 rekod, di mana hanya 20 (Model Seimbang) atau 24 (Model yang ditapis secara spasial) rekod digunakan untuk membina model kesesuaian habitat. Dengan menggunakan model ini, kami meramalkan habitat sesuai untuk Musang Hitam Pudar tertumpu kepada bahagian pertengahan Borneo yang berbukit-bukau, bersamaan dengan bahagian utara kompleks "Heart of Borneo". Walaupun terdapat beberapa kawasan terlindung yang bertaburan di dalam kompleks ini, kebanyakan kawasan terlindung ini tidak diurus dengan cekap; malah kebanyakannya menghadapi masalah pembalakan, penerokaan, pemburuan dan perlombongan secara haram. Kawasan di sekeliling kompleks ini terdiri daripada konsesi pembalakan, dan kebanyakan konsesi ini mungkin akan ditukar kepada kawasan perladangan di mana tiada bukti Musang Hitam Pudar boleh hidup. Untuk memastikan pemuliharaan spesies ini, lebih banyak kajian secara mendalam dan pemantauan dengan menggunakan perangkat kamera, perlu dilakukan di seluruh Borneo. Kajian yang mendalam perlu dilakukan di semua jenis habitat untuk memperbaiki model yang sedia ada supaya dapat memberi maklumat yang lebih manfaat kepada rancangan pemuliharaan spesies ini. Sehingga lebih banyak maklumat didapati, tindakan yang sewajarnya perlu diambil seperti penguatkuasaan undang-undang hidupan liar dan meningkatkan rondaan di sekitar kawasan-kawasan terlindung, serta menggalakkan amalan perhutanan yang berkekalan (sustainable) di konsesi-konsesi balak di sekeliling.

INTRODUCTION

Hose's civet *Diplogale hosei* (Thomas) is one of the world's least known carnivores (Yasuma, 2004). Endemic to Borneo, only about 17 museum specimens are known, all collected before 1984 (Van Rompaey & Azlan, 2004). The species was first described by Oldfield Thomas in 1892, from a specimen collected by Charles Hose in north-eastern Sarawak, Malaysian Borneo. Thomas (1892a) initially described it as *Hemigale hosei*, later changed to *Hemigalus hosei* by Trouessart (1898–1899). Thomas (1912) himself subsequently erected for it the distinct genus *Diplogale*, because of differences in the skull, dentition and colouration of pelage from the type species of *Hemigalus* Jourdan, the more common banded civet *H. derbyanus* (Gray). Pocock (1933) and Davis (1958) retained *Diplogale*, although some later authors classified it again as *Hemigalus* (e.g., Medway, 1977; Payne et al., 1985) until Corbet & Hill (1992) restored *Diplogale*. This nomenclature is now widely accepted (e.g., Hon & Azlan, 2008; Jennings & Veron, 2009) and a recent phylogenetic analysis confirmed the warranting of the monotypic genus *Diplogale* by Wilting & Fickel (2012).

Hose's civet (Fig. 1) resembles the banded civet in external appearance (Thomas, 1912), having similar size and proportions (Thomas, 1892b), with adults weighing about 1.5 kg (Van Rompaey & Azlan, 2004). Hose's civet, however, does not share the complex pelage pattern of the banded civet, but instead is bicoloured, with dark smoky brown to blackish upperparts and whitish underparts (Thomas, 1892b; Francis, 2002). Very little is known about the ecology of Hose's civet (Van Rompaey & Azlan, 2004), although morphological adaptations such as the broad, square-fronted muzzle (Thomas, 1892b), long whiskers (Banks, 1931) and partly webbed feet with patches of hair between the footpads (Payne et al., 1985) suggest a specialist forager for small animals such as fish, shrimp, crabs and frogs (Yasuma, 2004) amongst mossy boulders and streams (Payne et al., 1985). Hose's civet is thought to be crepuscular and nocturnal (Mathai et al., 2010a) and largely ground-dwelling, although one of Tom Harrison's specimens was listed "in jungle (treetops)" (Medway, 1965). It is thought to make dens in holes between rocks and/or tree roots (Yasuma, 2004). Nothing is known of population densities, home-range size or dispersal patterns.

On Malaysian Borneo, Hose's civet is listed on the Schedules of Totally Protected and Protected Species as 'Protected' under the Sarawak Wild Life Protection Ordinance (1998) and the Sabah Wildlife Conservation Enactment (1997), implying limited protection and lenient punishment to offenders. It is not listed as a protected animal in Brunei



Fig. 1. Hose's civet *Diplogale hosei* camera-trapped in the Protected Zone of the Sela'an Linau Forest Management Unit, Upper Baram, northern Sarawak, Malaysia on 19 July 2012. (Photograph by: John Mathai/HOSCAP Borneo.)

under the Brunei Wild Life Protection Act (1978) nor on Indonesian Borneo under the Appendix of the Government of Republic of Indonesia Regulation No. 7 (1999), although it was not known to occur in Kalimantan until recently (Samejima & Semiadi, 2012). It is not a CITES-listed species (CITES, 2015), presumably because it is unlikely to occur in international trade, given its rarity and rather plain pelage. Under The IUCN Red List of Threatened Species (Hon & Azlan, 2008), it is listed as Vulnerable, reflecting its naturally highly restricted range and extensive habitat loss within that range. It is possible the species could qualify for a higher threat category once more information is available on its ecology and threats; hence, research is urgent.

RESULTS AND DISCUSSION

Species occurrence records. Very few Hose's civet records were available for modelling and hence, the results should be treated with caution. Of the 43 collated, nine were excluded from modelling because of low spatial precision (over 5 km; Categories 4 and 5), but 17 had high precision (within 2 km; Category 1) and were collected between 2001 and 2011 (Table 1). Most records were collected from the mountainous interior of northern Sarawak and Sabah (Fig. 2); no records from Kalimantan were available at the time occurrence records for the modelling were collated. Only 20 (Balanced Model = M_1) or 24 (Spatial Filtering Model = M_2) records were used for modelling (see Kramer-Schadt et al. (2016), for detailed methodology).

Habitat associations. The respondents of the questionnaire were inconsistent in their assessment of suitable land-cover for Hose's civet (Table 2). Although lower montane forest was ranked overall as very good habitat for the species, individual responses ranged from very poor to very good. Similarly, upland forest and upper montane forest, though overall ranked as good, had individual responses ranging from very poor to very good habitat. This inconsistency in individual responses suggests there is little knowledge on suitable habitat for Hose's civet, and more intensive surveys

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Table 1. Summary of occurrence records for Hose's civet *Diplogale hosei* 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	17	7	9	17
Category 2 500 m – 2 km	1	1	1	1
Category 3 2–5 km	16	12	14	4
Category 4 above 5 km	9	–	–	3
Category 5 (no coordinates*)	0	–	–	0
Total	43	20	24	25

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

Table 2. Land-cover reclassification for Hose's civet *Diplogale hosei* based on the questionnaire results of eight respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	2.00	1–4
Upland forest	2.75	1–4
Lower montane forest	3.39	1–4
Upper montane forest	2.17	1–3
Forest mosaics/lowland forest	1.00	*
Forest mosaics/upland forest	1.13	#
Swamp forest	0.71	0–1
Mangrove	0.00	0–0
Old plantations	0.50	0–3
Young plantations and crops	0.17	0–1
Burnt forest area	0.17	0–1
Mixed crops	0.00	0–0
Bare area	0.00	0–0
Water and fishponds	0.00	0–0
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).

in all types of habitat are needed to improve current models and inform conservation planning. Lowland forest was ranked marginally suitable (possibly suitable as corridors) whereas forest mosaics (both lowland and highland) were ranked very poor habitat. Respondents were more consistent in their assessment of unsuitable habitat, all agreeing that mangroves and mixed crops were unsuitable, and most agreeing that swamps and young plantations and crops were unsuitable. Old plantations were, overall considered poor habitat, but had individual rankings from unsuitable to good. Based on this habitat assessment and the distribution of occurrence records, predicted core habitat for Hose's civet was restricted to an area of highland forest in the interior of north-eastern Borneo (Fig. 3). This region, located largely in the central

'Heart of Borneo', a government-led and NGO-supported agreement signed between Brunei Darussalam, Malaysia and Indonesia to manage sustainably the remaining relatively less-encroached band of forests in the centre of the island, is predominantly upland and montane forest. But there are records of the species from lowland forest (e.g., Francis, 2002; Wells et al., 2005; and since this modelling study, Samejima & Semiadi, 2012 in Central Kalimantan), so a focus on elevation in explaining the species's habitat use will probably miss important determinants.

Habitat suitability index (HSI) model. The current distribution predicted by the modelling process suggested the following important localities and conservation actions

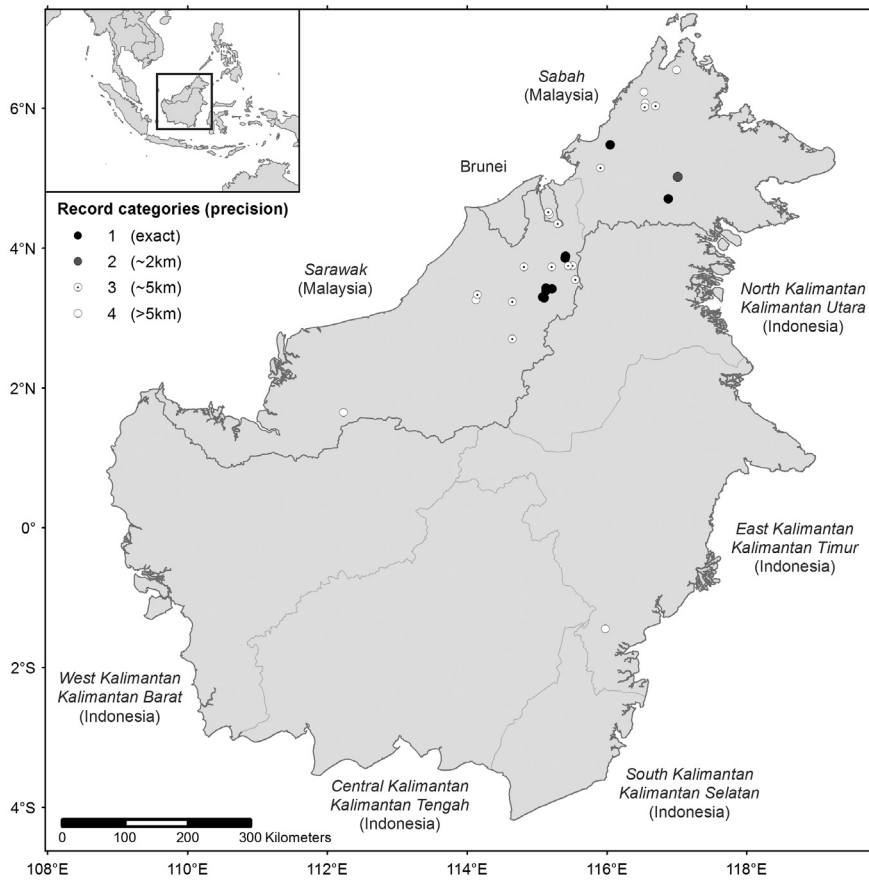


Fig. 2. Location of Hose's civet *Diplogale hosei* occurrence records across Borneo, showing spatial precision categories as well as countries and state boundaries.

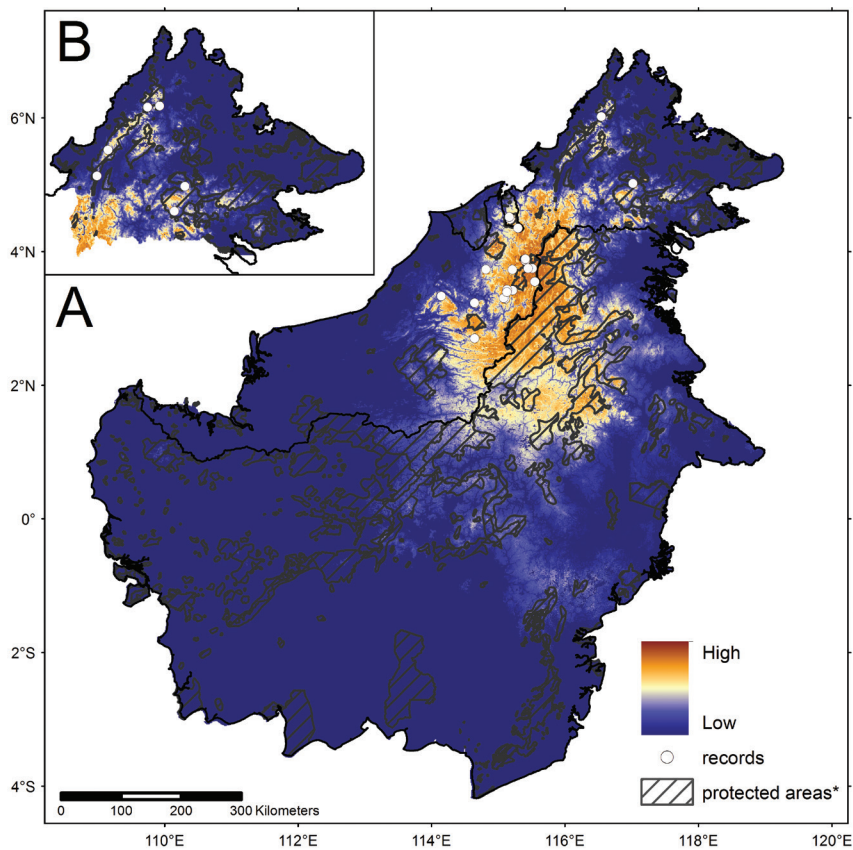


Fig. 3. Predictive Habitat Suitability Index (HSI) models for Hose's civet *Diplogale hosei* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al. (2016).

(see Fig. 3). Given the paucity of records and lack of understanding the species's ecology, the conservation measures suggested here are preliminary pending additional and better information.

Brunei Darussalam. Much of the remaining forest in Brunei Darussalam is lowland forest and was not predicted to be suitable habitat for Hose's civet. However, search effort in Brunei has been too low to allow conclusion that paucity of records means rarity or unsuitability of habitat. The southernmost tips of Ulu Temburong National Park and the Sungai [=River] Ingei Protection Forest were, however, predicted to be suitable. Ulu Temburong National Park is the largest protected area in Brunei Darussalam, comprising lowland forest, with upland and montane forest in the southern portion. It is the site of the only live capture of a Hose's civet to date (Yasuma, 2004) although the species should not be assumed to be restricted in the country to this site. The forest catchment of the Sungai Ingei in the interior of the Belait district comprises a mosaic of heath forest (kerangas), peat forest and upland forest. Local communities do hunt, although the intensity is thought to be low (Ahmad, 2014); of more concern might possibly be poaching of animals (potentially including Hose's civet, if they came across it) by foreign gaharu [aloewood *Aquilaria* Lam.] collectors (e.g., in Lim & Anak, 2010) who usually hunt during expeditions (Wollenberg, 2001). Increased enforcement (including patrolling) are necessary to protect Hose's civet and other threatened wildlife in these forest complexes; Sungai Ingei Protection forest, in particular, is located near Sarawak's Mulu National Park, an area predicted by the model to be key habitat for the species, thereby offering critical trans-boundary forest connectivity.

Sarawak, Malaysia. Interior northern Sarawak was predicted to contain habitat important for Hose's civet. Much of this largely upland and montane forest straddling the Kalimantan border is part of the 'Heart of Borneo' complex, comprising a mosaic of totally protected areas (e.g., National Parks), logging concessions (e.g., Forest Reserves), State Land and Native Customary Land. This includes Paya Maga (forest reserve), the Pulong Tau complex (comprising Pulong Tau National Park, the Kelabit Highlands, Tama Abu Range and surrounding forest reserves), Apad Lunan (forest reserve and native customary land), the Mulu-Gunung [=Mount] Buda complex (comprising Mulu National Park, Gunung Buda National Park and surrounding forest reserves), Linau Danum (forest reserve), Usun Apau complex (comprising Usun Apau National Park and the surrounding mosaic of forest reserves, state land and native customary land) and Gunung (= Mount) Dulit (forest reserve), while the Hose-Laga mountains (comprising the proposed Hose Mountains National Park, the proposed Batu Laga Wildlife Sanctuary and surrounding forest reserves and native customary land) was considered marginally suitable habitat for the species. The Kelabit Highlands in the Pulong Tau complex provided the largest series of collected specimens (Davis, 1958) and recent camera-trapping in a nearby logging concession revealed the greatest reported number of Hose's civet encounters to date (Mathai et al., 2010a, b). Logging is ongoing in many of

the forest reserves, in some cases followed by conversion to monoculture plantations (e.g., oil palm, acacia or rubber). The species's use of monoculture plantations remains unknown, given the low survey effort inside them. Hunting might be another potential threat given the species's ground-dwelling nature and the indiscriminate use of snares and nets. A further threat is the planned construction of a series of large hydroelectric dams (Sovacool & Bulan, 2013) within the area predicted to contain suitable habitat for the species. The proposed Baram dam alone, situated near the Kelabit Highlands, is expected to inundate an area of forest more than 400 km² and displace more than 20,000 indigenous people (Shirley & Kammen, 2013), potentially increasing intensity of shifting agriculture and indiscriminate hunting in the shrinking available habitat. Because of few records and paucity of research on the species, it is difficult to make any evidentiary recommendations other than the need for in-depth ecological studies and further basic inventories. Precautionary measures pending better information seem appropriate and include increased enforcement (including patrolling) activities, control of illegal hunting and snaring, and maintaining landscape connectivity among areas in Sarawak, Ulu Temburong National Park and Sungai Ingei Protection Forest in Brunei Darussalam, Kayan Mentarang National Park in Kalimantan and the Sipitang and Ulu Padas forest reserves in Sabah, all of which were predicted as high suitability areas for Hose's civet and two of which have records of the species (Ulu Temburong National Park (Francis, 2002; Yasuma, 2004) and Ulu Padas Forest Reserve (Brodie et al., 2015)).

Sabah, Malaysia. As in Sarawak, high suitability Hose's civet habitat was predicted along the mountain ranges. This includes Kinabalu Park and Crocker Range Park in the west of Sabah, where camera-trapping has recorded the species (e.g., Wells et al., 2005; AJ Hearn, pers. comm.). Both national parks are surrounded by villages, the inhabitants of which depend, presumably, to a certain extent at least, on forests for their livelihood and on wildlife for their protein. Harvest may therefore be of concern, especially by aloewood collectors (e.g., in Lim & Anak, 2010), who use snares commonly, although the population-level effects of present hunting levels remain unknown. This could be addressed by working with local communities and understanding their traditional use of surrounding forests and Hose's civet response to present harvest levels. A recent proposal to link the two national parks, known as the Kinabalu Ecological Linkage (Kinabalu Eco-Linc), is a promising step for the long-term conservation of wildlife in the area and ensuring connectivity between these two key Hose's civet sites (see also Wilting et al. (2016b) for Borneo ferret badger). Moreover, this region, together with Gunung Lumaku and the second major forest complex in Sabah suitable for Hose's civet, the Sipitang-Ulu Padas Forest Reserves in the south, form a continuous trans-boundary forest block with Paya Maga Forest Reserve in northern Sarawak, as part of the 'Heart of Borneo' initiative. The northern reaches of the Sipitang-Ulu Padas forest reserves have been logged and a large portion has been converted to industrial tree plantations (mainly *Acacia* Miller). Nonetheless, with proper

management, this area has the potential to be important for Hose's civet conservation. The third key area for Hose's civet in Sabah is the Maliau Basin – Imbak Canyon Conservation Area, located in south central Sabah. Currently managed by Yayasan Sabah for conservation, research, training and education, and nature recreation, this region comprises forest types including tropical heath (kerangas) and cloud forests. Recent camera-trapping has documented Hose's civet in these areas (Brodie & Giordano, 2011; Matsubayashi et al., 2011). This region is important for many wildlife species and hence, enforcement (including patrolling) needs to be increased to address the potential threat of harvest.

North Kalimantan, Indonesia. In North Kalimantan, the 1.4 million hectare Kayan Mentarang National Park is the largest protected area in Borneo and predicted to contain habitat highly suitable for Hose's civet, although the species was never recorded there, possibly reflecting inadequate survey to date. Kayan Mentarang National Park comprises several forest types and provides trans-boundary connectivity with important Hose's civet sites in Sarawak and Sabah such as the Pulong Tau complex and Ulu Padas Forest Reserve, respectively. However, large parts of the park are neither patrolled nor monitored, resulting in increased pressure from poaching, encroachment, illegal logging, local economic development and expansion of plantations and road networks (e.g., in Nijman, 2005). The Malinau Basin, connected in the north to Kayan Mentarang National Park, was considered marginally suitable for the species. This largely lowland forest is managed for commercial timber and mining and is exposed to numerous threats, similar to those in Kayan Mentarang National Park.

East Kalimantan, Indonesia. The Müller mountains, linking the national parks of Kayan Mentarang in North Kalimantan and Betung Kerihun in West Kalimantan, were predicted to contain marginally suitable habitat for Hose's civet. This mountain range lies between the provinces of East, North, Central and West Kalimantan and is thus an important area for ecological connectivity. Much of the landscape comprises timber concessions where logging is ongoing, ranging from conventional logging to reduced-impact logging practices (Brown et al., 2011). Other areas considered marginally suitable for the species were the hill forests surrounding the headwaters of the Sungai Mahakam, S. Len, S. Segah and S. Kelai. Many of these forests lie within timber concessions and face possible threats from unsustainable logging and poaching. Inventory work using camera-traps is needed to check for presence of Hose's civet; if confirmed in these areas, then ecologically sensitive management strategies and increased enforcement activities are likely to be necessary because these areas could function as corridors improving the overall functionality of these potential conservation sites.

South Kalimantan, Indonesia. South Kalimantan was considered unsuitable habitat for Hose's civet, potentially merely reflecting the extremely low survey and search effort in the province. More intensive surveys are needed, particularly in the Pergunungan [=Mountains] Meratus, to ascertain presence or absence of the species. A possible explanation

for the apparent unsuitability of South Kalimantan is its climatic distinctiveness; it is more seasonal than the rest of Borneo, with a pronounced dry season (extracted from Hijmans et al., 2005, 2015). This difference in local climate and the isolation of the province's mountain range from the central spine of interior Borneo make it probably unlikely to hold the species.

Central Kalimantan, Indonesia. Central Kalimantan was generally predicted to contain habitat unsuitable for Hose's civet, probably because of low search effort. However, some areas in the north bordering West Kalimantan, such as the Schwaner mountains and Bukit Baka–Bukit Raya National Park, might contain marginally suitable habitat for the species. Since the records were collated for the model, Samejima & Semiadi (2012) recorded Hose's civet in the Schwaner mountains, underlining the caution required when interpreting the model's results and emphasising the need for more data to improve such models and to inform conservation planning. Logging is ongoing in much of this area and hunting might be a potential threat to wildlife including Hose's civet (Samejima & Semiadi, 2012).

West Kalimantan, Indonesia. West Kalimantan is largely understudied compared with other parts of Borneo and was thus generally predicted to contain habitat unsuitable for Hose's civet. Nonetheless, the Gunung Niut Nature Reserve in the northwest of the province and Betung Kerihun National Park in the northeast were predicted to contain marginally suitable habitat for the species. Gunung Niut Nature Reserve contains lowland, upland and lower montane forests, but is isolated from other potential Hose's civet habitat. Hunting is a potential threat as is the expansion of oil palm plantations. Betung Kerihun National Park contains mainly highland ecosystems and provides transboundary connectivity to two protected areas in Sarawak, the Lanjak Entimau Wildlife Sanctuary and Batang Ai National Park. More surveys are needed in this area, as is increased enforcement (including patrolling activities) to reduce the potential threats of illegal logging and mining, poaching and encroachment.

RESEARCH PRIORITIES

The ecology of Hose's civet is almost unknown, with most information derived from a few direct sightings and camera-trap images of the species from the mountainous interior of Sarawak and Sabah. More surveys in other habitat types and areas, particularly in Kalimantan, are needed to evaluate the habitat associations of Hose's civet. A case in point is the recent record of Hose's civet from a logging concession in the Schwaner mountains, Central Kalimantan (Samejima & Semiadi, 2012): this area was predicted to be only marginally suitable, reflecting modelling constraints in areas with low search effort. This record is at least 500 km from any previous record (e.g., Francis, 2002; Dinets, 2003; Yasuma, 2004; Wells et al., 2005; Mathai et al., 2010a, b; Brodie & Giordano, 2011; Matsubayashi et al., 2011) and, at 325 m above sea level (a.s.l.), is over 100 m lower in elevation than the lowest previous record (in Brunei), at 450 m a.s.l. (Francis, 2002), in itself is regarded as an unusually

low record. The site where the species was detected is more than 30 km from the nearest montane area, suggesting that lowland forests may be a part of the main habitat for Hose's civet, at least in this area (Samejima & Semiadi, 2012). Based on the previous piecemeal understanding of the species and the predictive model's results, it is unlikely that this site would have been selected for deeper ecological research of the species. This highlights the need for further basic inventory work using camera-traps across Borneo, particularly in areas surrounding these lowland records. Ecological studies emphasising fine-scale habitat use are also needed. These can use occupancy methods, with data derived from camera-traps or hair-snares, although Hose's civet has not yet been studied by the latter method. Radio-telemetry would provide more detailed information on habitat selection and potential corridors but it remains unknown how Hose's civet could be successfully trapped (J. Mathai et al., unpublished data).

Another important question regarding Hose's civet is its dispersal abilities. Because the species's distribution appears to be patchy across montane regions, it is unclear if dispersal may be affected by habitat fragmentation as suitable habitat becomes increasingly isolated. It is also unclear whether individuals can disperse through a matrix of logged forest and monoculture plantations to ensure exchange between possibly subdivided populations. Further, it remains unknown how the increase of road networks in the interior of Borneo (Meijaard & Sheil, 2008) will affect dispersal.

GENERAL CONSERVATION ISSUES AND RECOMMENDATIONS

Pending sufficient information, precautionary conservation measures are currently sensible. Hose's civet was originally thought to be strictly montane (Payne et al., 1985; Jennings et al., 2013) although records from much lower elevations at 325 m a.s.l. (Samejima & Semiadi, 2012) and 450 m a.s.l. (Francis, 2002) demonstrate that the species can use lower-altitude forests. Similarly, that most records are from undisturbed forests (e.g., Yasuma, 2004; Wells et al., 2005; Brodie & Giordano, 2011; Matsubayashi et al., 2011) suggest a dependency on old-growth forest and intolerance to human-induced change in habitat; a recent modelling study by Jennings et al. (2013) concluded the species to be forest-dependent and restricted to evergreen forests. However, this could also in part reflect wide tendency to survey these habitats rather than modified landscapes (see also Mathai et al., 2016). Moreover, recent images within logging concessions from areas near logging roads (Mathai et al., 2010a, b; Samejima & Semiadi, 2012) might suggest some tolerance to modified landscapes. It remains unclear whether the species can persist in these more modified areas, whether they contain non-productive populations originating from nearby source populations, or whether they are dispersing individuals. Nevertheless, recent records indicate some degree of tolerance to selective logging, particularly in landscapes with large areas of old-growth forest. A precautionary conservation action for Hose's civet would thus be to ensure that forest reserves surrounding

key protected areas engage only in sustainable forestry practices such as selective logging. This would help ensure connectivity among sites of predicted high suitability and facilitate collaborative work between conservation biologists and the timber industry, particularly in the development of wildlife management plans, the location of corridors, and the rehabilitation of logged or burnt forests. This is in line with the vision of the 'Heart of Borneo' initiative and Hose's civet would benefit greatly from the implementation of this plan. Currently there is no evidence that the species can persist in monoculture plantations, but further research is needed to understand adaptability and dispersal of the species in monocultures. As a precautionary measure, road expansion through key areas should be minimised, to reduce fragmentation and effects of human access such as poaching, illegal logging and anthropogenic fires. Large strips of protected forest are also needed as habitat corridors between existing protected areas and areas of high suitability, in order to maintain dispersal and gene flow between subpopulations of the species. Committees including park staff and social scientists could work with local communities to enhance their sense of custodianship of the land and wildlife within, with the intent of addressing issues of encroachment and unsustainable wildlife harvest. Of particular concern is the potential killing of Hose's civet in snares and traps set for species such as chevrotains *Tragulus* Brisson, ground birds such as various pheasants, Phasianidae Horsfield, and porcupines, Hystricidae Fischer. Enforcement (including patrols) should be increased in priority sites, possibly by integrating local former hunters into anti-poaching patrols to curb illegal logging, mining and poaching. Another recommendation is to upgrade the status of Hose's civet to Totally Protected in Sarawak and Sabah, and list the species as protected in Brunei Darussalam and Kalimantan. Only through further research, effective management, a commitment to sustainability, and a holistic attitude towards conservation from all stakeholders concerned, can the long-term conservation of the endemic Hose's civet be ensured.

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