# Carnivore conservation planning on Borneo: Identifying key carnivore landscapes, research priorities and conservation interventions

Article *in* The Raffles Bulletin of Zoology · May 2016

**12 authors**, including:

**Erik Meijaard**
Borneo Futures, Brunei
**607** PUBLICATIONS   **9,825** CITATIONS

SEE PROFILE

**Gabriella Margit Fredriksson**
University of Amsterdam
**88** PUBLICATIONS   **1,652** CITATIONS

SEE PROFILE

**Marc Ancrenaz**
HUTAN
**229** PUBLICATIONS   **6,151** CITATIONS

SEE PROFILE

**Andrew J Hearn**
University of Oxford
**78** PUBLICATIONS   **1,184** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Pygmy Elephant Conservation Genetics View project

The capacity of forests to protect regional climate under global warming View project

# Carnivore conservation planning on Borneo: identifying key carnivore landscapes, research priorities and conservation interventions

John Mathai[1], J.W. Duckworth, Erik Meijaard, Gabriella Fredriksson, Jason Hon, Anthony Sebastian, Marc Ancrenaz, Andrew J. Hearn, Joanna Ross, Susan Cheyne, Borneo Carnivore Consortium and Andreas Wilting

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

**Abstract.** Borneo harbours more endemic carnivores than does any other island in the world except Madagascar, and almost half of the Bornean carnivore species have been classified by The IUCN Red List of Threatened Species as globally threatened. Here, a systematic conservation planning framework highlighted key carnivore landscapes, conservation research and intervention priorities, and gaps in current knowledge of Bornean carnivore ecology. All single-species predictive habitat suitability index (HSI) models presented in this issue (20 species, comprising all carnivores on Borneo except otters [Lutrinae] and sun bear *Helarctos malayanus*) were standardised by converting HSI values into binary maps, and combined to derive species richness maps to discuss and delineate areas of conservation priority. The highest predicted carnivore species richness (defined here as the sum of the binary threshold maps), corresponds to interior lowland, upland and lower montane forest, whereas areas with lowest predicted species richness correspond to coastal lowlands already largely converted to oil palm plantations. The 12 proposed areas of conservation importance for carnivores focus on large landscapes and connectivity between subunits, many centred around the tri-national Heart of Borneo initiative, with additional areas for wetland/lowland species. A large proportion of these proposed conservation landscapes are being exploited for commercial purposes (e.g., logging concessions) and would, therefore, improve in conservation value if their management became more sustainable. The most important research priorities for Bornean carnivores are species resilience to altered and fragmented landscapes; under-surveyed regions; and the effects and relative intensity of hunting across the island. The most pressing conservation interventions include conservation research on the most threatened Bornean carnivores: the Bornean ferret badger *Melogale everetti* and Hose's civet *Diplogale hosei* (highland endemics), and the flat-headed cat *Prionailurus planiceps* and otter civet *Cynogale bennettii* (wetland specialists). Targeted conservation research and integration of research findings into decision-making, maintaining and restoring connectivity, raising awareness and improving enforcement and governance are also important conservation interventions. Although more resources are needed for conservation and research, the joint effort of scientists, conservationists and government authorities in the identification of key carnivore landscapes, research priorities and conservation issues which this study presents raises hope that more targeted conservation efforts for Bornean carnivores will follow in the future.

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

**Abstrak (Bahasa Indonesia).** Wilayah Borneo memiliki paling banyak karnivora endemik dibandingkan pulau lainnya di seluruh dunia, selain Madagaskar. Hampir setengah dari keseluruhan jenis karnivora yang ada di Borneo masuk dalam kategori terancam pada daftar IUCN Red List of Threatened Species. Disini, suatu kerangka perencanaan konservasi yang sistimatis menyoroti kawasan kunci karnivora, prioritas penelitian dan intervensi aspek konservasi, serta kesenjangan dari pengetahuan mengenai ekologi karnivora di Borneo. Semua model pendugaan Index Kesesuaian Habitat (IKH) pada setiap spesies yang disajikan dalam tulisan ini (20 spesies, terdiri atas semua spesies karnivora yang ada di Borneo terkecuali berang-berang [Lutrinae] dan Beruang Madu *Helarctos malayanus*) distandardisasi dengan mengkonversi nilai IKH ke dalam pemetaan binari, dan digabung untuk memperoleh peta kekayaan spesies guna dibahas dan ditetapkan wilayah prioritasnya. Nilai pendugaan kekayaan spesies karnivora tertinggi (sebagai jumlah dari peta ambang binari), adalah selaras dengan bentuk hutan pedalaman dataran rendah, hutan dataran tinggi dan hutan pegunungan dataran rendah, sedangkan wilayah dengan pendugaan kekayaan spesies karnivora terendah adalah selaras dengan bentuk pantai dataran rendah yang telah berubah sepenuhnya menjadi perkebunan kelapa sawit. Dua belas wilayah dicanangkan sebagai wilayah penting untuk dikonservasi bagi karnivora, terpusat pada bentang alam yang luas dan saling berhubungan diantara sub-unit, kebanyakan berpusat di sekitar area Heart of Borneo di tiga negara, dengan wilayah tambahan untuk spesies dataran rendah atau lahan basah. Sebagain besar dari wilayah yang dicanangkan ini merupakan wilayah yang telah banyak dieksploatasi untuk tujuan komersil (konsesi hutan) dan dapat meningkatkan nilai konservasi manakala pengelolaannya bersifat berkelanjutan. Prioritas terpenting untuk penelitian karnivora Borneo adalah kesanggupan spesies beradaptasi pada wilayah yang terfragmentasi; wilayah-wilayah dalam area survey, serta pengaruh dari perburuan di semua wilayah pulau. Intervensi konservasi terpenting mencakup penelitian konservasi pada karnivora Borneo yang paling terancam: Biul Slentek *Melogale everetti* dan Musang Gunung *Diplogale hosei* (endemik dataran tinggi), serta Kucing Tandang *Prionailurus planiceps* dan Musang Air *Cynogale bennettii* (spesialis lahan basah). Penelitian wilayah konservasi terpilih dan integrasi temuan hasil penelitian kedalam penetapan kebijakan, menjaga dan memperbaiki

konektivitas, peningkatan kesadaran dan peningakatan penegakan hukum serta kebijakan, juga penting dalam intervensi konservasi. Walaupun banyak sumberdaya dibutuhkan untuk konservasi dan penelitian, kerjasama antara peneliti, konservasionis dan otoritas pemerintah dalam mengidentifikasi bentang alam kunci karnivora, prioritas penelitian dan isu konservasi dari hasil penelitian ini memberi harapan akan lebih banyak upaya konservasi terplih untuk karnivora Borneo bakal terbentuk di masa mendatang.

**Abstrak (Bahasa Malaysia).** Di Borneo terdapat paling banyak karnivora endemik (tidak didapati di tempat lain) dibandingkan kepulauan lain di dunia kecuali Madagascar dan hampir separuh daripada spesis karnivora ini tersenarai sebagai terancam di atas IUCN Red List of Threatened Species. Suatu rangka perancangan pemuliharaan yang sistematik digunakan untuk mengenalpasti landskap karnivora yang penting, kajian pemuliharaan yang mustahak dan tindakan utama yang perlu diambil serta mengenalpasti kekurangan dalam pengetahuan terkini mengenai ekologi spesis karnivora Borneo. Kesemua model peramalan kesesuaian habitat (HSI) bagi setiap spesis yang dikemukakan di dalam edisi ini (20 spesis kesemuanya, iaitu semua karnivora di Borneo kecuali memerang [Lutrinae] dan Beruang Madu *Helarctos malayanus*) diseragamkan dengan menukarkan nilai-nilai HSI kepada peta binari, dan kemudiannya digabungkan untuk menghasilkan peta kekayaan spesis yang seterusnya digunakan untuk membincangkan dan menggambarkan kawasan pemuliharaan yang terpenting. Kekayaan spesis karnivora (ditakrifkan di sini sebagai jumlah peta ambang binari (binary threshold)) yang tertinggi bersepadan dengan hutan kawasan pedalaman tanah rendah, tanah bukit dan pergunungan rendah, manakala kawasan yang bersepadan dengan ramalan kekayaan spesis terendah bersepadan dengan tanah rendah di pinggir laut yang sebahagain besarnya sudah ditukar kepada ladang kelapa sawit. 12 kawasan terpenting yang dicadangkan bagi pemuliharaan karnivora Borneo menekankan landskap besar dan sambungan di antara setiap unit. Kebanyakan landskap pemuliharaan karnivora ini tertumpu kepada kompleks 'Heart of Borneo' namun lebih banyak kawasan lain juga diperlukan, terutamanya untuk menampung kerperluan spesis tanah rendah dan tanah lembap/lahan basah (wetlands). Sebahagian besar landskap-landskap pemuliharaan yang dicadangkan sedang dieksploitasikan untuk kegiatan komersial (seperti konsesi balak) dan oleh itu, nilai dan prestasi pemuliharaanya akan meningkat sekiranya cara pengurusannya menjadi lebih mampan/berterusan (sustainable). Jenis kajian yang paling diperlukan terhadap karnivora Borneo adalah kajian tentang daya ketahanan terhadap habitat yang diubahsuai dan difragmentasikan; kajian di kawasan-kawasan yang jarang dipantau; serta kesan dan kadar relatif aktiviti pemburuan di seluruh Borneo. Tindakan pemuliharaan yang terpenting termasuk menjalankan kajian pemuliharaan terhadap spesis karnivora Borneo yang paling terancam: Pulasan Lamri *Melogale everetti* dan Musang Gunung *Diplogale hosei* (haiwan endemik kepada hutan tanah tinggi) serta Kucing Hutan *Prionailurus planiceps* dan Musang Memerang/Musang Air *Cynogale bennettii* (haiwan-haiwan yang terhad kepada lahan basah). Selain ini, kajian pemuliharaan yang disasarkan serta integrasi hasil kajian ke dalam proses membuat-keputusan; mengekalkan dan memulihkan sambungan di antara habitat yang tepencil dan terfragmentasi; dan meningkatkan kesedaran, tahap penguatkuasaan dan pentadbiran, merupakan tindakan pemuliharaan yang penting. Walaupun lebih banyak sumber diperlukan untuk menjalankan aktiviti pemuliharaan dan kajian, namun usaha-sama ini di antara kalangan ahli sains, ahli pemuliharaan dan pihak kerajaan untuk mengenalpasti landskap karnivora dan jenis kajian yang penting serta isu-isu pemuliharaan yang dikemukakan di dalam kajian ini, meningkatkan harapan untuk usaha-usaha pemuliharaan yang lebih tertumpu terhadap karnivora Borneo di masa depan.

---

## INTRODUCTION

The rapid rate of decline towards global extinction of mammals (Hoffman et al., 2011) has urged the conservation community to accelerate efforts towards a deeper understanding of species distributions, population trends, threats and conservation status (Belant et al., 2013). This growing concern of the species extinction crisis, and the recognition that there are limited conservation funds to address it, should have a profound influence on conservation planning. With a focus on relatively large spatial areas or regions, including areas allocated to both economic exploitation and protection for conservation purposes, there is a need to identify priorities and implement conservation actions within a practical yet science-based planning framework (Groves et al., 2002). A structured framework for conservation planning is necessary to enhance the effectiveness with which science informs conservation by clarifying the social and economic implications of alternative methods or scenarios, and reviewing the effectiveness of political processes for achieving stated biodiversity goals (Margules & Pressey, 2000).

A systematic, science-based conservation planning framework is especially important in the context of Borneo (Runting et al., 2015; Struebig et al., 2015a), identified as an evolutionary hotspot hosting the highest levels of mammalian species richness within South-east Asia (de Bruyn et al., 2014). Borneo has been identified as a global priority for carnivore conservation (Schreiber et al., 1989; Di Marco et al., 2014), with almost 50% of its carnivore species being categorised by The IUCN as globally threatened (i.e. Critically Endangered, Endangered or Vulnerable) (IUCN, 2015), and with more endemic carnivore species than has any other

[1]Leibniz Institute for Zoo and Wildlife Research, Alfred-Kowalke-Strasse 17, 10315 Berlin, Germany (formerly: IBEC, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia; Wildlife Conservation Society (WCS) Malaysia Program, 7 Jalan Ridgeway, 93200 Kuching, Sarawak, Malaysia); Email: johnmathai11@gmail.com

island in the world except Madagascar (Belant & Wilting, 2013). In response to these threats and to the paucity of knowledge, almost 200 national and international scientists, conservationists, naturalists and local stakeholders from the range states of Brunei Darussalam, Malaysia and Indonesia, the three countries comprising Borneo, participated in the Borneo Carnivore Symposium (BCS) in June 2011.

This paper summarises the key achievements of the BCS and the subsequent species distribution analyses, via a community perspective on Bornean carnivore distribution with a focus on threatened species to highlight conservation research and intervention priorities. A unique feature of the BCS was the formation of regional working groups for each of the four main geopolitical units on Borneo: Brunei Darussalam, Sarawak (Malaysia), Sabah (Malaysia) and Kalimantan (Indonesia). Each regional working group proposed areas of conservation importance for carnivores based on available records and results of the predictive models, focusing on large landscapes with an emphasis on connectivity between sub-units. The results of the predictive species distribution modelling and the discussions of these regional working groups are summarised in text boxes 1–4 and emphasise research and conservation actions recommended for and in each proposed carnivore landscape.

## SPECIES-LEVEL ACHIEVEMENTS AND MILESTONES OF THE BCS

From the BCS, gaps in knowledge of Bornean carnivores were successfully addressed in some cases, and highlighted in others. The status of two species, the collared mongoose *Herpestes semitorquatus* Gray, and the Bornean ferret badger *Melogale everetti* (Thomas) (one of three currently recognised endemic carnivores on the island), had until the BCS been assessed on The IUCN Red List of Threatened Species as Data Deficient. Information gathered during the BCS allowed categorisation of both species: Bornean ferret badger as Endangered (Wilting et al., 2015) and collared mongoose as Near Threatened (Mathai et al., 2015a). The collection of occurrence records and the predictive models supported previous assumptions of the very small distribution of Bornean ferret badger, lending weight to the hypothesis that the species is endemic to the western Sabah mountain massif and hence has possibly the smallest distribution range of any carnivore in South-east Asia (Wilting et al., 2016b). In contrast, the number of collated occurrence records for collared mongoose was much greater, leading to the prediction that it should be widely distributed across Borneo (Hon et al., 2016).

An unexpected finding was the distribution of the Sunda stink-badger *Mydaus javanensis* (Leschenault, in Desmarest), which models predicted today to be widespread across the lowlands of Sabah, and patchily distributed in north-eastern Sarawak and North Kalimantan, but largely absent from the rest of the island, particularly the southern portion. Reasons for this patchy distribution, whether driven by the species's behaviour, ecology, hunting, or a mix of these, are speculative (see Samejima et al., 2016).

In addition to these species-specific findings, many community-level insights were generated. For example, the full compilation of records further showed even for the more widespread and common species an almost complete lack of records from South Kalimantan and large parts of West Kalimantan (see Kramer-Schadt et al., 2016: Fig. 2). This highlights the urgent need for more surveys in these provinces to gain a better understanding of species distributions in these regions. These community-level aspects form the bulk of this document.

## SUMMARY OF MODEL RESULTS AND PREDICTED CARNIVORE DIVERSITY ACROSS BORNEO

Occurrence records were collated for all Bornean carnivores except the sun bear *Helarctos malayanus* (Raffles); based on these records, predictive models were developed for all remaining carnivores except otters (Mustelidae: Lutrinae Bonaparte): altogether, 20 species. Methodology is detailed in Kramer-Schadt et al. (2016). Because of the paucity of occurrence records for the four species of otter known to occur on Borneo, Asian small-clawed otter *Aonyx cinereus* (Illiger), Eurasian otter *Lutra lutra* (Linnaeus), hairy-nosed otter *Lutra sumatrana* (Gray) and smooth-coated otter *Lutrogale perspicillata* (Geoffroy Saint-Hilaire), these species were excluded from modelling and thus do not have species accounts in this supplement. The scarcity of modern records in itself shows that otters are likely to be among the most threatened Bornean carnivores and that, urgently, they need further research and conservation attention. The low number of otter records may reflect several factors. First, few observers are able to tell the different otter species apart under field conditions. Hence, records of otters usually need to be classified as unidentified to species. Second, otters are restricted largely to wetland and riverine habitats, making them vulnerable to the effects of deforestation and degradation: lowlands and wetlands experience the highest deforestation rates on Borneo (Gaveau et al., 2014). Third, their high dependence on semi-aquatic habitat makes them vulnerable to the effects of water pollution, caused by, among others, run-off from oil palm plantations, where fertilisers and pesticides are used commonly, and from mining, where chemicals are used heavily (McCarthy & Zen, 2010). Fourth, few surveys are conducted in wetland and riverine habitat, possibly because of difficult field conditions and lesser interest on the part of decision-makers and researchers in such habitats than in rainforest. Finally, South-east Asian otters are hunted and traded for their skins (Poole, 2003; Shepherd et al., 2011), which perhaps resulted in population declines on Borneo, although there is no evidence yet of such declines.

For the remaining 20 species, individual predictive habitat suitability index (HSI) models were standardised by converting the HSI values into binary maps, separating the predictions into suitable and unsuitable at two different thresholds. The commonly applied 10% and 25% omission error thresholds were used to yield a liberal and a conservative suitability prediction, respectively, allowing for some leeway
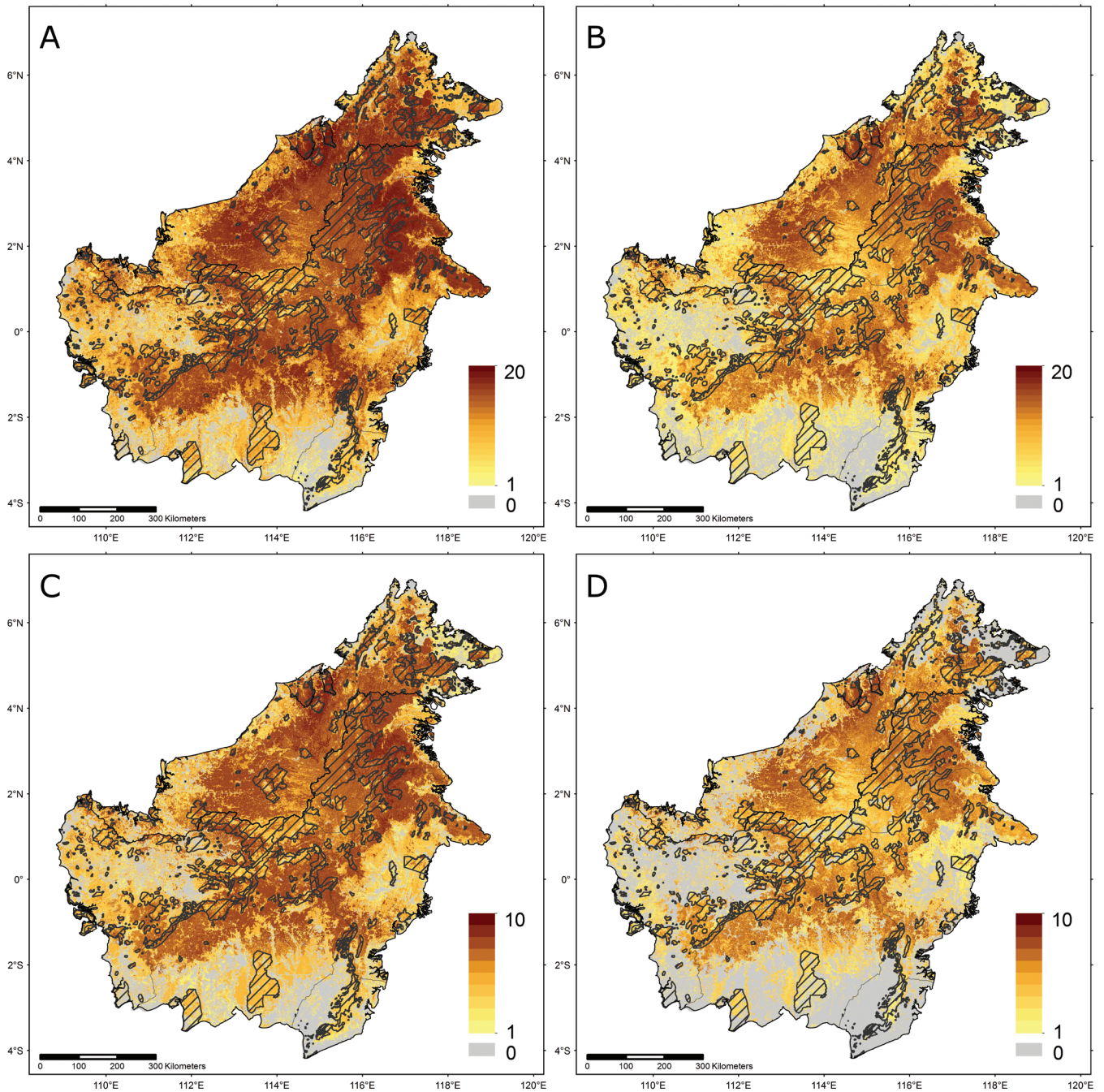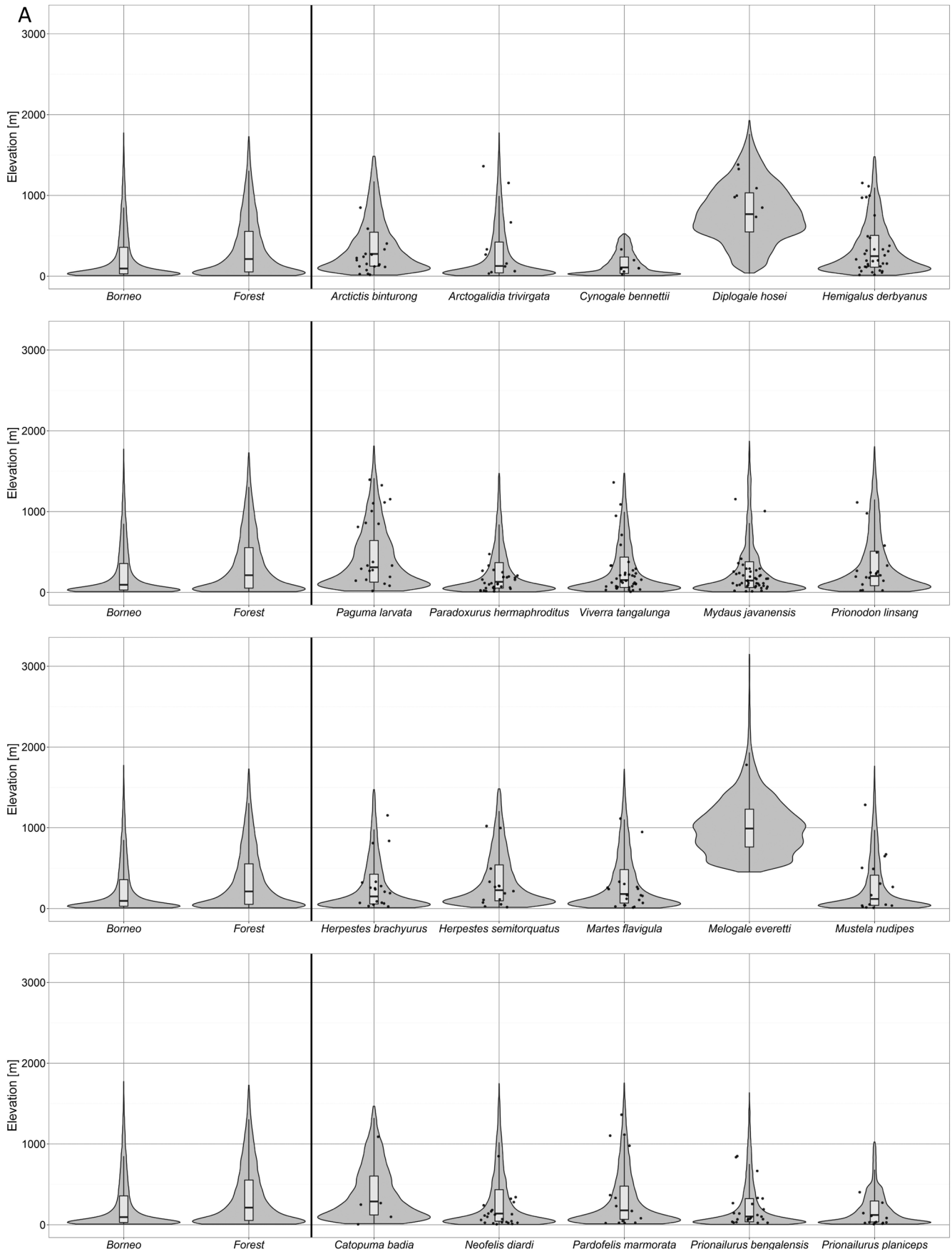
Fig. 1. Predicted total carnivore species richness (A & B) and globally threatened and Near Threatened carnivore species (BCS priority species) richness (C & D) across Borneo. A (all 20 species) and C (the 10 BCS priority species) show predicted species richness at the 10P (conservative/predicted broader species' distribution) and B (all 20 species) and D (the 10 BCS priority species) show the predicted richness for the strict 25P threshold (predicted core species' distribution).

in interpreting model results. These threshold maps were then combined to map areas with the highest species richness of carnivores. Highest predicted carnivore richness, here defined as the sum of the binary threshold maps, corresponds to interior lowland, upland and lower montane forest (Fig. 1A [10P, conservative threshold (predicted broader species' distribution)] and 1B [25P, strict threshold (predicted core species' distribution)]; threshold values are explained in more detail in Kramer-Schadt et al. (2016) and Struebig et al. (2015b)). These areas include most of Brunei; large areas of south to central Sabah; much of interior northern and central Sarawak; much of North Kalimantan; the northern parts of East Kalimantan; the northern half of

Central Kalimantan; and the interior eastern portion of West Kalimantan bordering Central Kalimantan. Much of this area corresponds to the larger 'Heart of Borneo' (HoB) initiative, a government-led and NGO-supported agreement signed between Brunei, Malaysia and Indonesia to manage sustainably the remaining relatively less-encroached band of forests in the centre of the island, straddling the mountains that run from Gunung [=Mount] Kinabalu in the northeast to the Pergunungan [=mountain range of] Schwaner–Müller in the south-west. The various totally protected areas (TPAs; IUCN protected area categories I and II) scattered throughout this range account for less than 20% of the area. However, when considering all protected areas (PAs; including TPAs
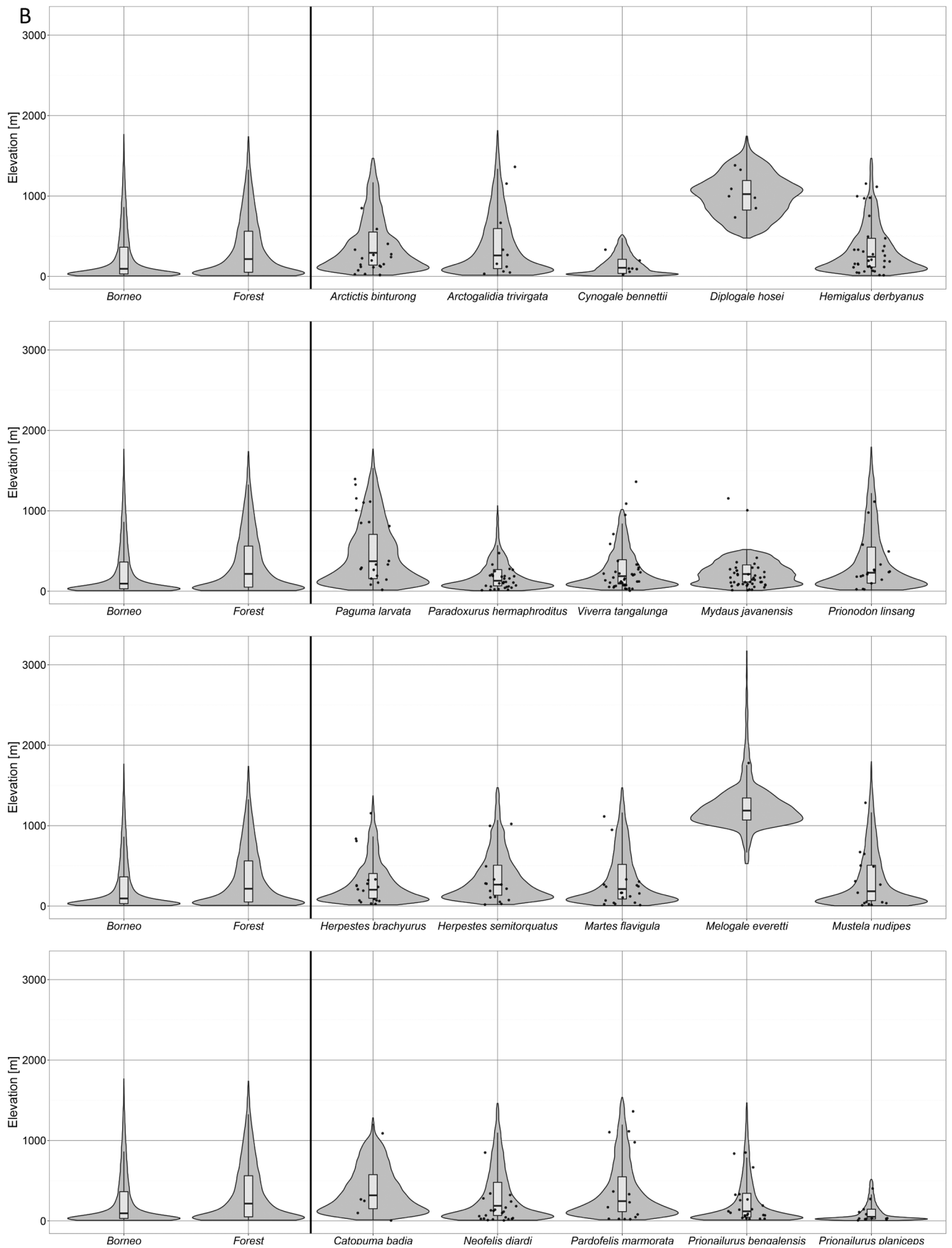
Fig. 2. Elevation ranges of the predicted species distributions, represented as violin plots at the 10P (conservative/broader altitudinal range; A) and 25P (strict/core altitudinal range; B) thresholds. First two violin plots on each panel represent the elevation ranges of total land area and forested area on Borneo, to facilitate comparison. Violin plots represent kernel density estimates of elevation range of predicted 1 km² grid cells. The median altitudinal preference and interquartile range for each species are shown in the corresponding box plot. Actual records for each species (only category 1, i.e., where precise geographic coordinates were available) are represented as black dots; placement of black dots is arbitrary on either side of the vertical midline.

Table 1. Land area for each of the 12 proposed carnivore landscapes across Borneo, according to geopolitical units and percentage protected.

| Geopolitical Unit | Proposed Carnivore Landscape | Total Area (km²) | % Area under TPAs | % Area under PAs |
|---|---|---|---|---|
| Borneo | HoB (Total) | 233,234 | 18.1 | 38.1 |
| | All carnivore landscapes, including HoB (Total) | 328,412 | 17.0 | 35.0 |
| Brunei | HoB (No. 1) | 4066 | 29.5 | 29.5 |
| Sarawak | HoB (No. 1) | 21,834 | 17 | 18.7 |
| | Extended Baram Complex (No. 2) | 15,900 | 5 | 5 |
| | Central Sarawak Complex (No. 3) | 10,475 | 1 | 15 |
| | Rajang Delta–Saribas–Tanjung Datu Complex (No. 4) | 2500 | 39 | 39 |
| | All carnivore landscapes | 50,709 | 11 | 15 |
| Sabah | HoB (No. 1) | 39,088 | 26.9 | 27.3 |
| | Tabin–Kinabatangan Wetlands (No. 5) | 3340 | 66 | 66 |
| | All carnivore landscapes | 42,428 | 30 | 30 |
| South Kalimantan | Pergunungan Meratus (No. 6) | 7500 | 3 | 53 |
| Central Kalimantan | HoB (No. 1) | 30,342 | 11.7 | 36.7 |
| | Sabangau Complex (No. 7) | 10,380 | 54 | 56 |
| | Tanjung Puting NP (No. 8) | 5100 | 60 | 67 |
| | Arabela–Schwaner Landscape (No. 9) | 11,400 | 0 | 7 |
| | All carnivore landscapes | 58,025 | 21 | 37 |
| West Kalimantan | HoB (No. 1) | 48,901 | 20.8 | 47.5 |
| | Arabela–Schwaner Landscape (No. 9) | 6510 | 0 | 40 |
| | West Kalimantan Western Wetland Complex (No. 10) | 5970 | 16 | 30 |
| | All carnivore landscapes | 61,381 | 18 | 45 |
| East Kalimantan | HoB (No. 1) | 37,954 | 0 | 36.9 |
| | Wehea–Mangkalihat–Sangkulirang complex (No. 11) | 12,180 | 0 | 11 |
| | All carnivore landscapes | 50,134 | 0 | 31 |
| North Kalimantan | HoB (No. 1) | 51,049 | 25.3 | 48.4 |
| | Sebuku–Sembakung Complex (No. 12) | 3120 | 0 | 1 |
| | All carnivore landscapes | 54,169 | 24 | 46 |

TPAs: totally protected areas; PAs: protected areas.

Information used to identify the proposed carnivore landscapes is described in the text, and descriptions on the landscapes are found in the regional text boxes 1–4. Landscapes are shown in Fig. 4. Note that other than the Heart of Borneo (HoB) (Carnivore Conservation Landscape No. 1), all other delineated carnivore landscapes are drawn for visualisation purposes only and not defined by provincial or forest reserve borders. Therefore, the percentages under protection shown here are only estimates.

and, mainly in Kalimantan, Forest Reserves such as Hutan Lindung [= Protection Forest], as defined in Struebig et al., 2015a: Supplementary Material), this figure corresponds to 38% of the area (see Table 1). Most of the area within the HoB is currently licensed as concessions for logging (the dominant industry by area), plantation agriculture (mainly for oil palm, wood and paper-pulp) and mining (although mining currently occurs in only small areas of the HoB, exploration rights have been issued in over 40% of the region; WWF, 2015). To ensure that the HoB initiative conserves carnivores on Borneo, and many other Bornean taxa (Beck et al., 2011; Struebig et al., 2015a), it needs to be implemented on the ground and not just remain a well-intentioned vision.

Areas with the lowest predicted carnivore richness were mainly coastal lowlands in South, Central and West Kalimantan. There are several reasons why this pattern is observed. First, deforestation rates have been highest in coastal lowlands where human settlements and plantation agriculture (e.g., oil palm and paper-pulp) have expanded rapidly (see Kramer-Schadt et al., 2016: Fig. 3B); in these human-dominated landscapes, the remaining forests are severely fragmented and only generalist species with a high tolerance to modified landscapes can survive (Fitzherbert et al., 2008). Second, most of Kalimantan, particularly South and West Kalimantan, is generally under-surveyed relative to the rest of the island and the low predicted habitat suitability is likely to reflect this. Third, south-eastern Borneo has a greater seasonal climate variation than elsewhere on the island, including a more pronounced dry season (see Kramer-Schadt et al., 2016: Fig. 3A) and it remains little known (because of low survey effort) which species occur under such climatic conditions.
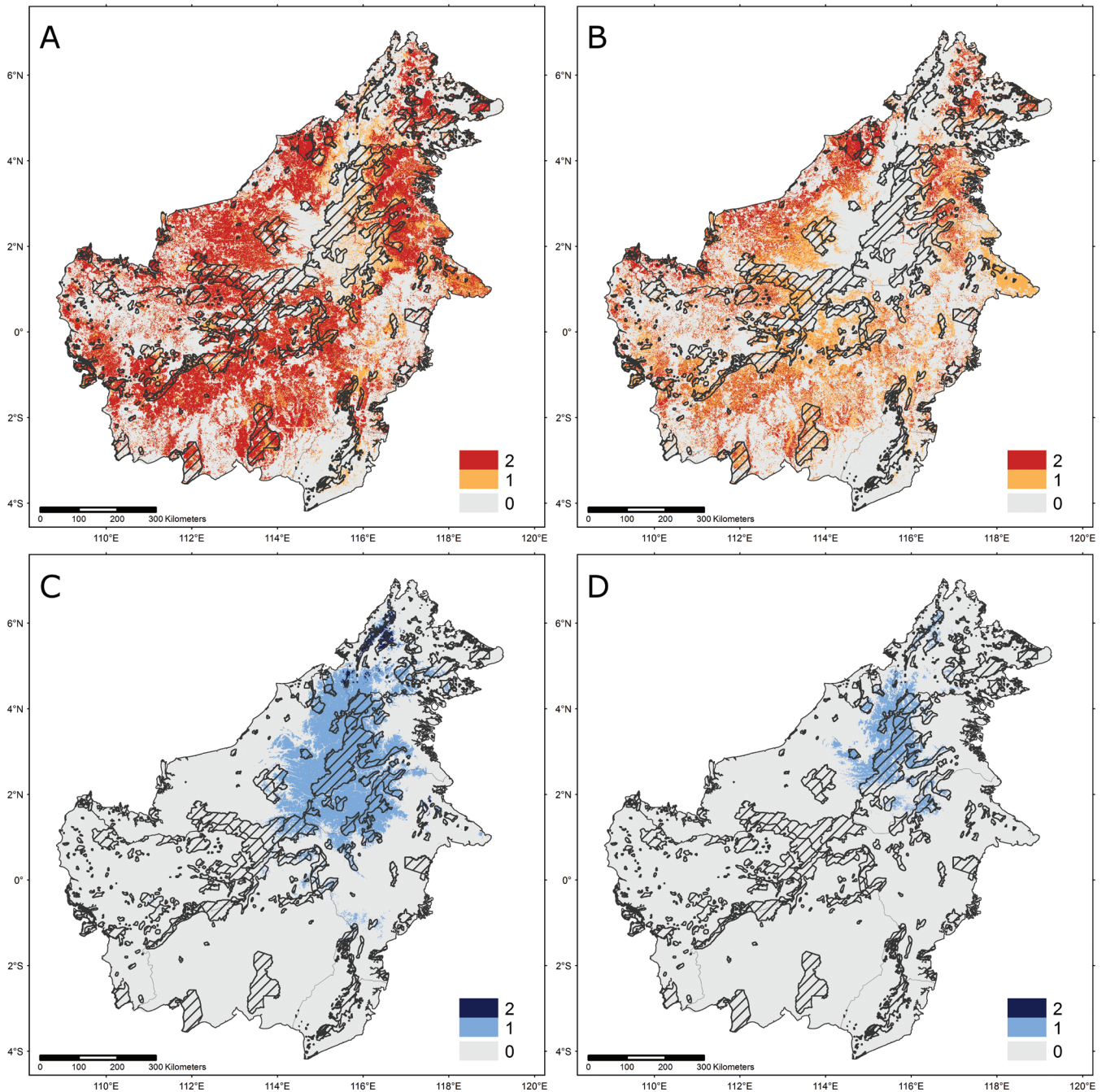
Fig. 3. Sum of predicted occurrence of wetland/lowland (A, B) and highland (C, D) specialist carnivores across Borneo. A and B show predicted occurrence for wetland/lowland specialist carnivores (flat-headed cat *Prionailurus planiceps* and otter civet *Cynogale bennettii*) at the 10P (conservative/broader species' distribution; A) and 25P (strict/core species' distribution; B) thresholds. C and D show predicted species occurrence for highland specialist carnivores (Bornean ferret badger *Melogale everetti* and Hose's civet *Diplogale hosei*) at the 10P (conservative/broader species' distribution; C) and 25P (strict/core species' distribution; D) thresholds.

A similar pattern is found for the subset of the 10 globally threatened and Near Threatened species (hereafter, 'BCS priority species'; Wilting et al., 2016a: Table 1 gives status on IUCN Red List), where interior central Borneo has the highest richness (Figs 1C, D). The lower carnivore richness predictions for the coastal lowlands are even more pronounced for the subset of BCS priority species than they were for all carnivore species. For BCS priority species, the low richness is predicted also for converted, degraded and fragmented areas in Sarawak and Sabah. This reflects the lower adaptability of BCS priority species to modified landscapes and fragmentation.

**Altitudinal distribution of species across Borneo.** Most of the land in Borneo is in the lowlands: 81.6% of the area lies below 500 m, 13.3% lies between 500 and 1000 m (uplands), 4% lies between 1000 and 1500 m (lower montane) and only 0.6% of the land area is above 1500 m (upper montane; Table 2). Within the lowlands, roughly 55% is still forested with some old growth, although mostly logged, forests (lowland, swamp and mangrove forest) and this corresponds to about 72% of the total currently forested area on Borneo; in the upland, lower montane and upper montane altitudinal bands, more than 95% of land remains forested, meaning the percentage of forest that falls within each of these altitudinal

Table 2. Altitude-specific percentages in Borneo for total land area, total land area under protection, total forested area, total forested area protected, and forested area within corresponding altitudinal band.

| Altitudinal Band | % of Total Land Area that falls within this Band | % of Total Land Area within this Band under Protection | % of Forested Area that falls within this Band | % of Forested Area within this Band under Protection | % of Corresponding Band that is still Forested |
|---|---|---|---|---|---|
| Under 500 m | 81.6 | 6.8 (13.4) | 71.7 | 9.0 (18.5) | 54.9 |
| 500–1000 m | 13.3 | 18.2 (42.8) | 20.3 | 17.4 (43.5) | 95.1 |
| 1000–1500 m | 4.0 | 31.8 (57.7) | 7.0 | 32.0 (57.5) | 98.2 |
| Over 1500 m | 0.6 | 40.3 (64.2) | 1.0 | 39.6 (63.1) | 96.2 |

Altitudinal levels: lowland (under 500 m), upland (500–1000 m), lower montane (1000–1500 m) and upper montane (over 1500 m). Protection figures are for totally protected areas (TPAs) with those for all protected areas (PAs) in parentheses. TPAs and PAs are defined in the text.

classes is higher than the corresponding percentage of land area within that altitudinal class (see Table 2). This shows that deforestation disproportionately affects the lowlands and that its effects are smaller at higher altitudes (see also Struebig et al., 2015a). Further, the percentage of forests falling under protection in the highlands is much higher (e.g., for forests above 1500 m, 39.6% lies within TPAs, 63.1% within PAs) than that in the lowlands (only 9% within TPAs, 18.5% within PAs, for forested areas below 500 m; see Table 2).

The larger availability of land in the lowlands means that before large-scale anthropogenic land-cover change occurred, the majority of carnivores, except highland specialists, were concentrated in the lowlands of Borneo, simply because this is where most land area is available. This is important for the interpretation and comparison of the elevation ranges of the predicted carnivore distributions, as shown in Figs 2A (10P) and 2B (25P). Even if the proportion of the predicted area of a species in a high altitudinal band is small, the corresponding land area available in that altitudinal band is also small, suggesting that the species has no altitudinal preferences and that its distribution is rather a reflection of the available land. Besides the available land area, the predominance of observer effort at lower and middle altitudes also influences the altitudinal distributions given in Figs 2A & B and therefore, the actual altitudinal breadth of the different species might be divergent.

**Wetlands and lowlands.** Models predicted that otter civet *Cynogale bennettii* Gray, and flat-headed cat *Prionailurus planiceps* (Vigors & Horsfield), are strictly wetland (and mostly lowland) specialists favouring peat swamp or lowland forests with many lakes and water bodies. High proportions of these habitats have already been converted to intensive agriculture (e.g., oil palm and other tree plantations, rice fields and aquaculture). Both species appear unable to use such highly modified habitats (Cheyne et al., 2016; Wilting et al., 2016c). From the binary threshold maps of both species, only 8.5% or 15.1% of their distribution range falls under TPAs and PAs respectively, at the 25P threshold. Thus, as well as being among the most habitat-restricted Bornean carnivores, they are also probably the most threatened. There appears some indication that both species may survive in fragmented

landscapes as long as forest persists along main rivers and tributaries and hunting pressure is low (see records for the Sungai [=River] Kinabatangan in Wilting et al., 2016c and A.J. Hearn unpublished data). Also, hairy-nosed otter falls in this category of wetland specialists (i.e., associated with peat swamp forest, freshwater swamp forest, mangroves or forested areas around lakes, rivers and their tributaries) and possibly Eurasian otter, at least in tropical Asia; Asian small-clawed otter and smooth-coated otter might similarly be associated with forested wetlands in present-day Borneo. It is unclear whether this association is purely ecological or whether hunting pressure plays a role too, because their non-forest potential range remains poorly surveyed with hunting levels not well known (see Meijaard, 2014). The clarification of ecological preferences and niches of all otter species will be possible only with further field research.

For the six wetland specialist carnivores (including otters) that occur on Borneo, the central HoB forest complex, which was predicted to have the highest carnivore species richness, might not be sufficient to safeguard their long-term survival (see Figs 3A & B). Instead, a network of small (under 100 km²) and medium sized (100–1000 km²), often highly fragmented protected areas and unprotected forest areas (often licensed for development), is important (see Figs 3A & B and text boxes 1–4 for the wetland priority areas in countries and states). Many of these priority areas are not included in the HoB initiative, are interspersed with plantations and human settlements, face high levels of threats from recurrent fires and deforestation, and thus require special conservation attention (Runting et al., 2015). This could take the form of conservation partnerships which promote forested corridors or reduced impact land-use practices within intervening agricultural mosaics, thereby enhancing connectivity between coastal protected areas and unprotected forest areas. To finance such initiatives, REDD+ (Reducing Emissions from Deforestation and Forest Degradation) or PES (Payment for Ecosystem Services) projects could be initiated because coastal lowlands provide ideal candidate areas through their often high soil-carbon content (especially in peat swamp forests) and their greater perceived threat compared with interior upland forests (Naidoo et al., 2008; Venter et al., 2009).

An additional potential threat faced by wetland specialists is the pollution of water bodies, for example from agrochemicals notably pesticides, use of poison in freshwater fisheries and chemicals in mining (Castilhos et al., 2006; Leong et al., 2007; Dudley, 2009). In this regard, there is a need for further investigation of potential pollution threats to each of these wetland specialists. Following this, awareness programmes need to be designed to sensitise local communities and plantation managers and employees on the susceptibility of these species (if and where relevant) to water pollution as well as the fragility of wetland ecosystems and their conservation importance. Particularly for wetland species, the thorough application of sustainable practices of the oil palm industry is of great importance. Sustainable management, according to the Roundtable for Sustainable Palm Oil (RSPO) guidelines (www.rspo.org), would reduce pollution of freshwater systems and help to restore riverine forests within oil palm plantations, which could function as corridors for wetland species. However, given the area and layout of oil palm, many such within-plantation riverine forest strips do not link large habitat-blocks for these wetland species. If, therefore, the strips themselves can directly support these species (this is not known), this would be an important, perhaps their chief, contribution, for these species. Although large parts of lowland forests and wetlands have already been converted to plantations, collaboration between the palm-oil industry and wetland conservation projects would be a promising start for successful, long-term conservation for Borneo's wetland carnivores.

**Uplands and highlands.** All three endemic Bornean carnivores, Bornean ferret badger, Hose's civet *Diplogale hosei* (Thomas), and Bornean bay cat *Catopuma badia* (Gray), along with masked palm civet *Paguma larvata* (Smith), were predicted to be associated with higher elevations. The association was much stronger for the former two (see Figs 3C & D; Mathai et al., 2016; Wilting et al., 2016b). Both bay cat and masked palm civet are known to occur locally in the lowlands (e.g., Belden et al., 2014). Compared with the two lowland and wetland specialists, the proportion of the predicted distribution range of Bornean ferret badger and Hose's civet which falls under protection is much higher at 46.6% (TPAs) or 54.8% (PAs), because forest conversion and habitat loss occurs mainly in the more productive and easily accessible lowlands. However, climate change could be a very serious threat for upper highland species because potential upslope range shifts are impossible (Struebig et al., 2015a). On Borneo, although altitudes go up to 4100 m, only 0.6% of the land area is above 1500 m; this implies that the loss of suitable habitat below 1500 m for these species would restrict their distributions to a tiny area, with drastic consequences on their population size. For example, potential habitat loss for Hose's civet through climate change alone is projected to be 77% by 2080 (Mathai et al., 2015b) and a similarly worrying outlook is expected for the Bornean ferret badger with its very small distribution range (see Wilting et al., 2016b).

**Wide altitudinal range.** The remaining species are predicted to be fairly widespread across Borneo, covering a wide altitudinal range and habitat type. Many of them are listed as Least Concern on the IUCN Red List and are tolerant, to a certain degree at least, of habitat degradation, fragmentation and altered landscapes; hence, they do not require urgent or targeted conservation attention. Although many species, for example common palm civet *Paradoxurus hermaphroditus* (Pallas), and Malay civet *Viverra tangalunga* Gray, appeared to prefer lowland forest to other habitat types (see Figs 2A & B), these species are so widely distributed that their wider use of lowlands is a simple effect of the greater area of lowland habitat available, and not a genuine preference per se. Six species with wide altitudinal ranges, however, might require attention based on their current IUCN Red List categorisation: sun bear, binturong *Arctictis binturong* (Raffles), banded civet *Hemigalus derbyanus* (Gray), marbled cat *Pardofelis marmorata* (Martin), and Sunda clouded leopard *Neofelis diardi* (Cuvier), all listed as Vulnerable (although banded civet and marbled cat were reclassified to Near Threatened on the latest version of the IUCN Red List, published online in November 2015), and collared mongoose, listed as Data Deficient (reclassified to Near Threatened on the IUCN Red List in November 2015). The two major threats to sun bear are habitat loss (through unsustainable logging, conversion of natural forest to other land uses, and forest fires) and commercial hunting (for its gall bladders and paws), although these threats are not evenly distributed throughout the range of the species (Fredriksson et al., 2008). Binturong is hunted in Borneo for food (Uluk et al., 2001; Murphy, 2007) and is known to be heavily traded in other parts of its global distributional range, mainly as food and on a smaller scale, as living trophies (e.g., Chutipong et al., 2014). Similarly, Sunda clouded leopard and marbled cat are hunted for their pelts and for ritual uses (Puri, 2001; Shepherd et al., 2011; Rustam et al., 2016) and possibly in the case of Sunda clouded leopard, as fake tiger bones (D'Cruze & Macdonald, 2015). Sunda clouded leopard in particular, but also, to a lesser extent, sun bear, binturong and marbled cat, are assumed to have large spatial requirements and Sunda clouded leopard is known to occur also in very low densities (Cheyne & Macdonald, 2011; Brodie & Giordano, 2012; Wilting et al., 2012). Therefore, large, contiguous forests are needed for these species, particularly because it is not known the extent to which they can disperse through monoculture plantations and tolerate altered and fragmented habitats. The situation for banded civet and collared mongoose is less dire: banded civet has recently been confirmed to have a wider altitudinal range than thought at the time of its 2008 IUCN Red List assessment, whereas collared mongoose is predicted to be widely distributed on Borneo.

## PRIORITY CARNIVORE LANDSCAPES ACROSS BORNEO

This study combined four aspects to highlight priority carnivore landscapes across Borneo (Fig. 4): (i) the summarised results of the predicted habitat suitability assessment for the 20 carnivores; (ii) the distribution of summed carnivore richness of all BCS priority species (globally threatened and Near Threatened species); (iii) the explicit needs of the wetland/lowland and highland
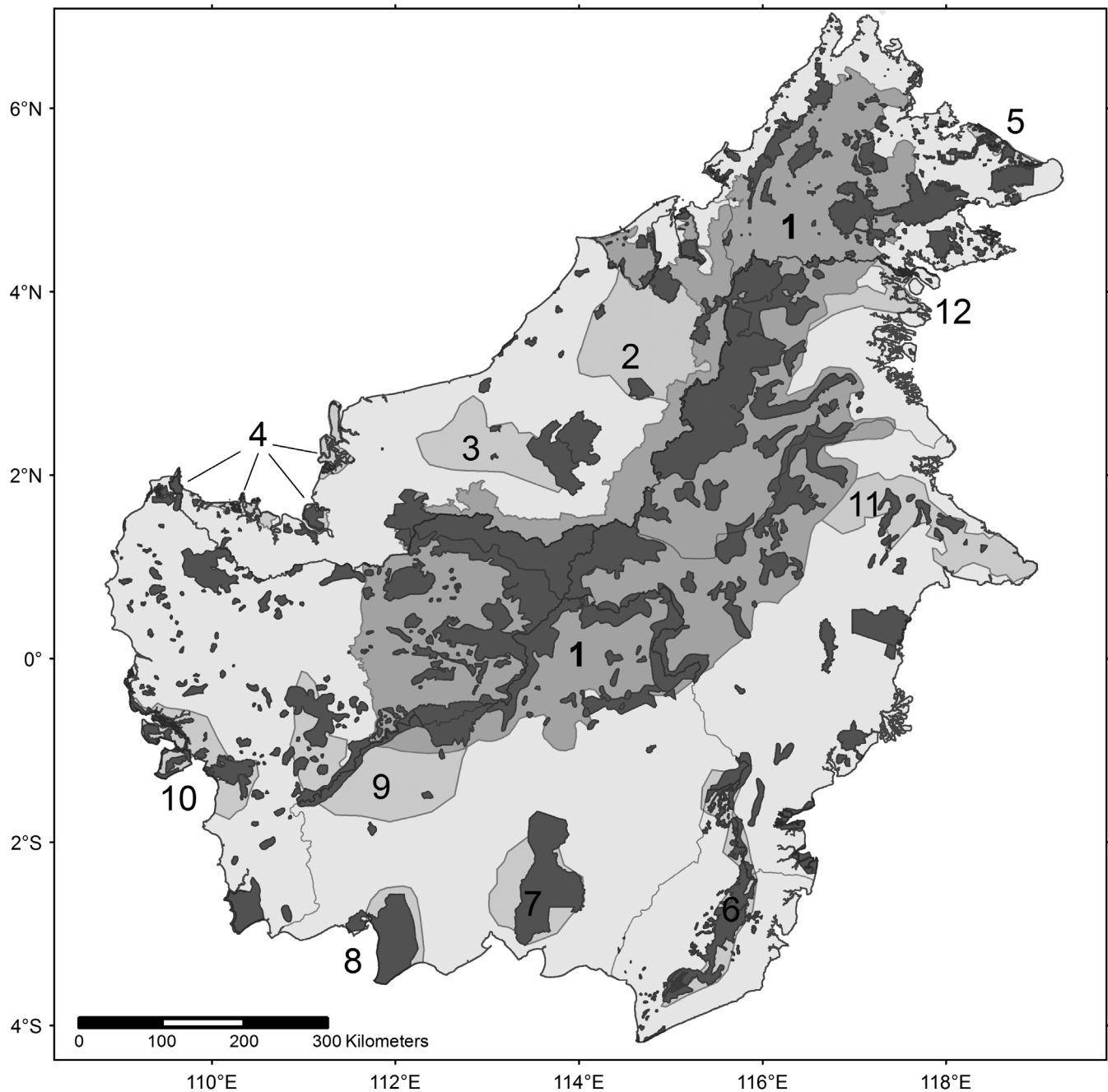
Fig. 4. Priority carnivore landscapes across Borneo. Information used to identify these landscapes is described in the text and descriptions of the landscapes are found in the regional text boxes 1–4. Three different grey tones represent (from darkest to lightest): (i) protected areas, PAs (note that in Malaysia and Brunei, totally protected areas [TPAs] are shown, whereas mainly in Kalimantan, forest reserves [including protection forests] are also presented [http://gislab.cifor.cgiar.org/wm/borneo/; Struebig et al., 2015a]; this map was updated with latest information provided by Sabah Forestry Department on recently protected areas in Sabah, Malaysia); (ii) the Heart of Borneo (HoB; i.e., Carnivore Conservation Landscape No. 1); (iii) additional proposed Carnivore Conservation Landscapes (numbered 2 to 12). Note that other than the HoB, all delineated carnivore landscapes are drawn for visualisation purposes only and have not been defined by provincial or forest reserve borders.

specialists, and (iv) respondent opinion, i.e. the knowledge and experiences of the participants of the BCS. Areas not highlighted during this study were often excluded not because they are presently unimportant for carnivores; rather, the selection of priority carnivore landscapes prioritised larger, contiguous and/or currently unprotected areas in dire need of conservation attention in favour of small, scattered and fragmented areas or already protected areas. Highlighted priority carnivore landscapes do not necessarily warrant being gazetted, even in part, as totally protected areas. A

flexible approach that integrates the needs of indigenous communities and economic development with those of the conservation and sustainable use of forests and wildlife could retain the carnivore conservation interest of these areas. Many proposed carnivore landscapes are centred around the forests of interior Borneo, earmarked by the tri-national HoB initiative (details about priority carnivore landscapes and needs at the provincial level within the HoB are given in the regional text-boxes 1–4) but additional areas are required to cater for the full range of Bornean carnivores.

Some extend the existing HoB to the southwest in Central and West Kalimantan (No. 9), to the north within Sarawak (No. 2) and to the east within East and North Kalimantan (Nos. 11 & 12, respectively; see regional text boxes & Fig. 4). However, most additional priority carnivore landscapes are located along the coastal wetlands and lowlands. In many cases, these wetland and lowland priority carnivore landscapes are already highly fragmented and small in size; hence, to maximise the long-term survival chances of Bornean wetland specialists, greater efforts are needed not just to conserve, but also to restore, the remaining habitat (see regional text boxes for details). One priority carnivore landscape which is neither a proposed extension to the HoB nor coastal wetland habitat is the Pergunungan Meratus (No. 6). This area has been only poorly surveyed and its carnivore assemblage is unknown. This knowledge gap, and the different climatic conditions in South Kalimantan compared with the rest of Borneo, might have resulted in unique ecological adaptations of species, highlighting the importance of including the Pergunungan Meratus chain as one of the carnivore research priority landscapes.

## CONSERVATION RESEARCH PRIORITIES ACROSS BORNEO

**1) Studies on adaptability to disturbed/altered habitat and fragmentation.** The protected area network on Borneo will be too small and/or too fragmented to ensure on its own the long-term survival of some, perhaps many, Bornean carnivore species. Hence, in the current era of large-scale modification and conversion of forested areas, conservation research focused on altered and fragmented landscapes is required to inform the integrated approaches of conservation and development that are going to be inevitable over the larger landscapes needed to conserve the carnivore assemblage of Borneo. However, a common denominator amongst all species' respondents was the low understanding of how well carnivores cope with anthropogenic habitat modification, such as selective logging and fragmentation. Further, very few studies focused on monocultures, particularly oil palm plantations. Thus, knowledge of whether, and if so, how each carnivore species uses these areas, is limited, even for the better-known leopard cat *Prionailurus bengalensis* (Kerr) (see Rajaratnam et al., 2007; Bernard et al., 2014; Yue et al., 2015). Although some species certainly use logged forest and plantations, and have some tolerance to habitat fragmentation e.g., leopard cat and Malay civet, the ability, if any, of such disturbed and altered habitat to support populations into the long term is unclear. For example, Wearn et al. (2013) detected all five species of Bornean cat in a highly disturbed commercial forest reserve in Sabah, including substantial populations of Sunda clouded leopard, bay cat and marbled cat; they stressed, however, that it remains to be known if these five species' populations would be viable in the long term and hence, echo previous assertions of the importance of little-disturbed forest. Further, species that are seen even regularly in disturbed habitat might use such landscapes as hunting grounds but still require forested areas for basic needs such as denning sites and breeding (Mohamed et al., 2016).

Considering the above, research relevant for and linked to conservation should move beyond protected areas. Although some of these areas provide comfortable research facilities and easier access, the understanding of carnivore occurrence in such habitats is reasonably complete, with the exception of otters. To influence land-use policy and advise development planning and conservation management, conservation scientists should turn their attention to non-protected areas that are exploited and transformed by various types of production such as forestry, agriculture or mining, and that are fragmented and further degraded by roads and human settlements (Meijaard et al., 2005; Streicher & Ulibarri, 2014). In these non-protected areas, clarifying the impacts that sustainable practices have on carnivore communities (as promoted by various certification schemes such as the Forest Stewardship Council (FSC) for timber exploitation or the RSPO for palm oil production) would inform understanding about how sustainable exploitation of non-protected areas and carnivore conservation could be combined. Research efforts should focus, for example, on riparian buffers of different widths within oil palm plantations and forested islands within logged forests and monoculture plantations, such as studies currently conducted under the SAFE (Stability of Altered Forest Ecosystems) project in Sabah. Studies should investigate the effects and relative intensity of hunting, as well as how infrastructure development, such as the building of road networks, human settlements and dams (notably their power lines) affect movement, whether they become barriers to dispersal and, if so, to what extent.

**2) Studies in under-surveyed habitats and areas.**

A) Wetlands, including peat swamp forest, freshwater swamps, mangroves and forests along lakes, rivers and their tributaries. Because of their often difficult field conditions and relatively low accessibility, wetland habitats are often overlooked by researchers or at best, surveyed only in areas surrounding existing research stations or easily accessible water bodies. More surveys are required in these habitats to understand their use by carnivores. A so-far neglected aspect that requires further study is the effect of pollution on wetland and mangrove systems, caused mainly by run-off from surrounding oil palm plantations, where fertilisers and pesticides are commonly used, and from mining, where chemicals, some toxic, are heavily used (Castilhos et al., 2006; Leong et al., 2007; Dudley, 2009). How, and to what extent this affects carnivores as apex predators, particularly wetland specialists and their prey species, needs to be investigated.

B) Highland forest above 1000 m. About 4.6% of the area of Borneo lies above 1000 m a.s.l. and much of this (roughly 97%), is forested (Table 2). Deforestation on Borneo currently affects the highlands less than the lowlands: the percentage of forests above 1000 m a.s.l. is almost double the available land percentage at that altitudinal class, at 8% (Table 2). However, very little of this area has been surveyed for carnivores. Nearly all carnivores' uppermost records on Borneo come from

lower, sometimes much lower, elevations than that in other parts of their range. It remains uncertain if this is a genuine reflection of low use of these high-elevation forests by Bornean carnivores, or a misleading effect of the limited use, to date, of appropriate survey methods in high-elevation forests on Borneo. Similarly for Bornean birds, a paucity of survey effort in high-altitude habitat meant many montane species had been overlooked (e.g., Brickle et al., 2010). Such highland surveys would potentially find new populations of the two threatened highland specialists, Bornean ferret badger and Hose's civet; and if they did not, they would emphasise the importance of the presently known localities for these species.

C) Under-surveyed regions. South Kalimantan province and surroundings remain hardly surveyed. Indeed many species, including common and wide-ranging ones such as leopard cat, common palm civet and short-tailed mongoose *Herpestes brachyurus* Gray, have no, or only very few, records from South Kalimantan. Kramer-Schadt et al. (2016: Fig. 2) maps all Bornean carnivore occurrence records available to BCS. Areas lacking records can be regarded as under-surveyed. Similarly, large parts of West Kalimantan have not been surveyed. The predictions of the habitat suitability models thus need to be treated with caution for these regions: although search-effort bias has been minimised during the modelling (Kramer-Schadt et al., 2016), these areas might still be underrepresented in the distribution maps because of their climatic distinctiveness (particularly south-east Kalimantan). Unless there are records sufficiently spatially precise to have been used in the model, the predictions cannot accurately reflect the potential of occurrence within these regions, because of the models' high weighting of climatic data. More surveys in these regions would determine whether the lower predictions of suitable habitat are because of the minimal survey effort or reflect a genuine lower suitability of these areas for these species, perhaps because of different climatic conditions or because large areas have been transformed to unsuitable land-cover (Kramer-Schadt et al., 2016: Fig. 3B). Additionally, a number of other scattered localities across Borneo would benefit from further surveys (regional text boxes 1–4 detail these areas).

**3) Studies on the effects of hunting.** Almost nothing is known about the effects of hunting on carnivore populations on Borneo and therefore, hunting ('hunting' includes here any removal for any purpose of dead or live animals, taken by whatever method, legally or illegally) was discussed at length during regional working group discussions at the BCS. It remains unknown if any carnivores are particularly targeted by hunters, whether any are seriously affected at the population level by the widespread use of snares on Borneo, and what effect poaching by people who travel in remote forest areas (e.g., gaharu [aloewood *Aquilaria* Lam.] collectors, gold prospectors and bird-catchers) have on species populations. Snares often target species such

as sambar *Rusa unicolor* (Kerr), bearded pig *Sus barbatus* Müller, chevrotains *Tragulus* Brisson, ground birds such as various pheasants (Phasianidae Horsfield), and porcupines (Hystricidae Fischer), although being indiscriminate in what they catch, carnivores might also be affected. In large parts of Indochina, carnivores are already heavily hunted (Corlett, 2007; Shepherd et al., 2011) and the extensive snaring means that a number of species are even threatened with local extinction (MacMillan & Nguyen, 2013; Coudrat et al., 2014a, b; Willcox et al., 2014). Such high levels of hunting of carnivores have so far not been reported or suspected in Borneo. Illegal hunting and trade is increasing and it is possible that intensive snaring of the sort now commonplace in Indochina might appear in Borneo as the former areas are defaunated (Shepherd et al., 2011). Species that might be targeted by hunters include civets (wild meat trade, pest), specifically palm civets (also for civet coffee ['kopi luwak'] trade and pet trade), otters (pelts, pest), sun bears (gall bladder, paws, pest), patterned cats (pelts), bigger cats (fake tiger bone), and almost any species for the novelty pet trade. It is suspected that Hose's civet, Malay civet, banded civet, otter civet, short-tailed mongoose, collared mongoose, Bornean ferret badger, Sunda stink-badger, Malay weasel and some of the cats might be particularly taken as by-catch in snares and other traps, because they spend a lot of their mobile time on the ground. Although some levels of hunting were reported by all regional working groups, hunting appears to be a bigger problem in Sarawak and the Kalimantan provinces than in Brunei (where hunting might have been more common in the past) and Sabah, possibly because in the former two, there are more (often non-Muslim) indigenous communities living in the forest who depend on wildlife for their protein and do not have, or have lost, religious or cultural hunting taboos (see also Bennett et al., 2000; Bennett & Gumal, 2001). Additionally, these local communities are increasingly driven by commercial incentives to hunt for specific items/species (GF pers. obs.) with access to remote areas being eased by logging and mining roads, as well as motorised, affordable, travel over rivers to remote upstream areas.

Scientists should focus on trying to understand how hunting patterns and wild meat consumption affect species populations. Off-take of different species by hunters and those who travel in remote forest areas, such as aloewood collectors, gold prospectors and bird-catchers, needs to be quantified and factors that influence this off-take (such as species' abundance, hunting methods, intrinsic preference of hunters, legislation and accessibility) need to be determined. Reasons motivating people to hunt, whether it be financial gain, social esteem, enjoyment or subsistence use, should also be assessed. Further, gaps in the awareness of hunters about wildlife protection laws and ordinances need to be understood and rectified (Meijaard et al., 2011). Wildlife trade needs to be monitored to detect and quantify potential increases in demand for wildlife and wildlife products. Such information, specific to Borneo, is critical to design more effective conservation interventions for those Bornean carnivores threatened by hunting.

**NECESSARY CONSERVATION INTERVENTIONS ACROSS BORNEO**

**1) More targeted conservation research and better integration of research findings in conservation decisions and interventions.** Research findings about the distribution and threats of species can improve the allocation of limited conservation resources. Hence, it is important that conservation decisions are based on research findings and that conservation research addresses more effectively the topics relevant to conservation decisions and management. For example, research findings can inform local stakeholders and conservation NGOs on the optimal balance for human and financial resources to reduce hunting pressure between enforcement (e.g., patrolling) activities (and if so, where, when, how and targeting whom in particular), education and awareness programmes (where, when, how and targeting whom), and the provision of alternative activities that meet the offenders' needs (again, where, when, how and targeting whom) (e.g., Davis et al., 2013). Knowledge of many Bornean carnivores' ecology and conservation needs (if any) is so limited that targeted species-specific conservation efforts are currently not applied. Here, joint efforts between local stakeholders (including government agencies) and scientists are needed to (i) generate the necessary understanding, (ii) use this knowledge for more effective conservation initiatives, and (iii) monitor the effectiveness of the initiatives.

**2) Maintaining connectivity.** The BCS proposed important carnivore landscapes across Borneo, some transcending provincial and international borders (Fig. 4; regional text boxes 1–4). Connectivity between individual units (e.g. protected areas) within the identified larger carnivore landscapes (habitat blocks) is often lacking, with the protected areas surrounded by plantations and timber concessions that often may not be managed sustainably. Mostly, land-units within the larger carnivore landscapes fall under a variety of management regimes such as protection, logging (both certified and uncertified), plantation agriculture (mainly oil palm and wood), native land and state land and the individual protected areas within these landscapes are frequently too small to function effectively on their own (Table 1 gives percentages of each carnivore landscape protected); thus, maintaining and rebuilding connectivity across these disparate landscapes is critical. Such connectivity can be provided by the establishment of wildlife corridors particularly along riparian forests, through reforestation programmes on degraded lands, or through reduced impact land uses in agricultural mosaics.

**3) Enforcement including patrolling.** The effects of hunting on Bornean carnivore populations are largely unknown: further research is imperative to understand these effects better. All evidence, including experience shared by local stakeholders in the regional working groups, indicates that hunting is a growing threat throughout the Bornean range occupied by carnivores, in both protected and non-protected areas (see also Bennett et al., 2000) . This includes hunting by people who travel in remote forest areas, local communities, logging company, plantation and construction workers,

urban recreational hunters and foreigners. Regionally, this problem is so severe that trade in wildlife, including parts and derivatives, has been identified as the leading factor threatening species survival (Wildlife Conservation Society and Sarawak Forest Department, 1996; Corlett, 2007). Although hunting levels of carnivores on Borneo are currently presumed to be lower than in some other parts of South-east Asia, high demand from China (and often neighbours like Vietnam) for animals such as pangolins *Manis* Linnaeus, and helmeted hornbill *Rhinoplax vigil* (J.R. Forster) (for casques), shows how quickly illegal hunting and trade can become a serious threat, even in Borneo (Zhang et al., 2015).

Apart from hunting, encroachment into protected areas or other forests is common, by local communities for shifting agriculture and expansion of settlements, by immigrants and by plantation companies (e.g., Santika et al., 2015). In some parts of Borneo, illegal logging is rampant, both within and outside protected areas (by local communities and logging companies) and in logging concessions themselves (by local communities and illegal re-entry into harvesting coupes by concession holders) (Gaveau et al., 2013). Illegal mining, although less extensive, occurs also largely unchecked, particularly in Kalimantan (Obidzinski et al., in prep.). Another problem more severe in the Kalimantan provinces is the use of fire in agriculture, particularly when opening up new areas for plantations. The incidence of forest fires increases near peat swamp forests which have been drained by canal to facilitate expansion of oil palm plantations and logging. Also, impoverished local people use fire for small-scale land clearance, hunting and in disputes over land ownership (Siegert et al., 2001). Intensified use of forest (e.g., for logging) increases fire susceptibility because of the degraded forest condition. In 1997–1998, 5.2 million hectares of land were affected by fires in East Kalimantan alone (Siegert et al., 2001), and 2015 is likely to have been the worst fire year since then (Meijaard, 2015). All these activities result in degradation, alteration or loss of habitat for wildlife, including carnivores.

In summary, there was general consensus that existing wildlife protection laws and ordinances are broadly appropriate on paper but they need to be enforced (see also Crees et al., 2015; Linkie et al., 2015). This can be achieved only through increased political commitment to effective wildlife conservation and strengthened community support. Demonstrating successful conservation and proving that there are social and economic co-benefits would help generate such support.

**4) Improved legislation, political will and governance.** Ineffective law enforcement is a constant theme in studies of threatened species and protected areas. It is maintained by various combinations of ignorance, tradition, affluence, corruption, greed, low funding, low political will, and low cross-border cooperation (Corlett, 2007). A strong legislative and implementation framework is key to the successful management of forests and wildlife, through effective enforcement. Existing legislation is broadly sufficient in content whereas implementation is highly patchy: rectifying

this is the law-related priority. The effectiveness of any legislation depends entirely on its level of implementation, especially on how well it is used as a weapon to deter wildlife criminals.

Recommendations to update existing legislation include mandating all logging concessions and plantations within the carnivore landscapes identified in this study (which are likely also to represent key areas for other animal groups) and the HoB initiative, to be certified for sustainable management. This is to ensure that logging and plantations within these key areas are carried out in a responsible and sustainable manner, as per the guidelines and criteria of certification bodies such as FSC and the RSPO. To retain sustainable carnivore populations across the proposed landscapes, it is not enough if only a few enlightened companies conduct their activities responsibly: governments of all three countries encompassing Borneo should ensure that all forestry and agriculture within these landscapes are conducted sustainably and ethically by incorporating this into legislation and then ensuring the legislation is enforced.

**5) Awareness raising.** Local communities have much of the necessary knowledge to manage forest resources sustainably (MacMillan &Nguyen, 2013) and can be a key component to manage and conserve Bornean carnivores outside protected areas. However, some investment will be required to build capacity and influence wildlife use in favour of conservation objectives. For example, education programmes to raise hunters' awareness of which species are considered globally threatened as well as respect for wildlife protection laws is often necessary because they may be unaware which species are protected and of protected area boundaries; also, this will ensure there is no possibility that a malefactor's potential ignorance of these matters could be used as an argument to withhold punishment. Such education programmes must be seen as just one component of a much wider programme which involves, among others, ensuring the availability of alternative sources of protein and income, such as animal husbandry programmes (Bennett & Robinson, 2000). Enforcement can also become more effective, particularly in reducing demand for wildlife products, if accompanied by education and awareness programmes, but this is far from widely implemented. Support from local communities is helpful for the long-term viability of protected areas and species populations but conservation programmes still often fail to garner their support on a large scale (Balmford & Whitten, 2003). The hiring of local community members, including former hunters as rangers, guides, or field assistants can help spread the benefits (Lynam et al., 2006; Ancrenaz et al., 2007).

Sustained awareness-raising efforts targeting businesses (e.g., restaurants and traditional medicine shops) and city-based consumers should be conducted also on the illegality of the trade and consumption of carnivores (see The Star Online, 2015). Also, social media can play an important role as an awareness and hunting monitoring tool: recent campaigns against people who uploaded images of the killing of sun bears and leopard cats led to police action and showed how effective social media can be in highlighting conservation problems and getting the legal attention they require (e.g., in Hidayat, 2015; Lajiun, 2015). More efforts should be expended into raising awareness, through social media, school programmes and education centres, to educate the public on Borneo's carnivores, particularly the Bornean endemics – Bornean ferret badger, Hose's civet and bay cat – because many of Borneo's carnivores, with the exception of Sunda clouded leopard and sun bear, are neither well known nor particularly charismatic. Finally, companies (logging, plantation and mining) play an increasing role in wildlife conservation and need to become partners in better management of carnivores. Companies often have the financial means and human resources to enforce anti-hunting laws locally and because of their political connections, they could potentially influence policy-making and implementation. Better management within these concession areas will benefit carnivores, especially those with greater adaptability to non-pristine forest conditions. With the general public taking a relatively negative view of the corporate sector, communication should clarify that good company management can make an important contribution to carnivore conservation.

**6) Partnerships for conservation.** Priority carnivore landscapes are likely to be managed more sustainably when there is broad participation of all stakeholders. Conservation partnerships should include, where relevant to the area and management approach, local communities, NGOs, government agencies, logging concessionaires, plantation managers, operators of tourism and other businesses within the landscape, and universities and research institutes. Further, such partnerships should include, among others, mechanisms such as certification schemes for sustainable management (e.g., FSC and RSPO, see also Struebig et al., 2015a), international-level awareness campaigns that incorporate better labelling of sustainable products, programmes providing market-based incentives for the protection of forests such as REDD+ and PES, and eco-investments as part of corporate social responsibility (CSR) programmes. These partnerships, and the mechanisms they allow, can ultimately be a powerful force for conservation, leading to market shifts that could benefit forests and wildlife, including carnivores.

## CONCLUSION

The framework of the BCS enabled scientists, conservationists and local stakeholders from the three countries comprising Borneo to share and review knowledge on the current status of carnivores on the island. Species-specific and carnivore-community conservation issues as well as carnivore landscapes were identified and highlighted. Further to these accomplishments, the main achievement of the BCS was to expose gaps in knowledge. A lot more work remains to be done, particularly in terms of understanding species' resilience to the fast changing landscape of Borneo. So far, research has often been conducted in accessible, clearly important protected areas, and avoided landscapes that are highly disturbed, potentially unimportant and/or difficult of access. Although this approach has increased knowledge

greatly about some rare species such as bay cat, it has led to disproportionately few data from highly fragmented and degraded landscapes, and from habitats difficult to survey such as peat swamps, mangroves and high-elevation forest. This uneven coverage directly hinders effective conservation: while some of the under-surveyed habitats doubtless do have little to contribute to Bornean carnivore conservation, equally the potential of some is, in general, surely under-estimated.

Further, there is a much larger presence of scientists, both international and local, working in Sabah than elsewhere in Borneo. A reason for this could be that the research permission application system in Sabah is more research-friendly. The paucity of research in other parts of Borneo, particularly some regions in Kalimantan, resulted in a much lower number of records and information. To allow knowledge-based targeted conservation interventions, conservation projects in such regions should be encouraged to start generating information of sufficient quality and quantity to allow them to devise, implement and monitor conservation actions effectively.

The priority carnivore landscapes highlighted in this study warrant due importance by decision-makers and new trans-boundary initiatives of research and conservation. Existing co-operative initiatives such as the HoB need to be pursued as do other conservation measures to ensure the three countries sharing Borneo protect its unique biodiversity and carnivore assemblage. The increasing levels of hunting and trade in wildlife and its derivatives necessitates enforcement cooperation between range countries to combat illegal cross-border hunting and trade. The BCS findings are only one step towards the long-term conservation of Borneo's carnivores. More resources are needed for conservation research, enforcement, training and designing more sustainable approaches for development. However, the joint efforts of scientists, conservationists and government authorities in the identification of key carnivore landscapes, research priorities and conservation issues for these species raises hope that more and better targeted conservation efforts can follow in the upcoming years.

**TEXT BOX 1: BRUNEI DARUSSALAM**

**General remarks.** Brunei still maintains substantial forest cover, particularly in terms of lowland forest and peat swamps, and many of these forests are connected to Sarawak. Although few records were collected from Brunei, reflecting generally low survey effort and low response from researchers working in Brunei, models predicted much of Brunei to contain suitable habitat for most carnivores, including globally threatened species and wetland species. Trans-boundary connectivity is an important consideration for Brunei in terms of creating large habitats for carnivores. Within Brunei itself, the priority conservation action should be to create and maintain connectivity between key areas to ensure larger continuous forests from the peat swamps and lowlands to the higher-elevation forests. Another priority is the protection and rehabilitation of Brunei's peat swamps. The peatlands of Brunei, covering almost 20% of the country and found mainly in western Belait district, are still closer to pristine than in other areas on Borneo, but face threats through development, peat drainage and fires.

**Conservation research priorities.**

A. Inventory surveys in key habitats, for example by camera-trapping.

B. Assessment of hunting levels and their effects on carnivore populations: currently, hunting might be a greater threat in Brunei than are habitat loss and degradation.

**Priority conservation interventions.**

A. Increase capacity of the Brunei Forest Department by employing and training more forest rangers to carry out enforcement activities (including patrolling), especially along the boundaries of protected areas and forest reserves.

B. Maintain and enhance connectivity, both between key areas within the country and with upland forested areas in Sarawak.

C. Restore and rehabilitate degraded peatlands, particularly in the Lower Belait Valley.

**Priority carnivore landscape.**

1. **Heart of Borneo** [29.5% under both TPA and PA – see Table 1 for details on estimation]

   i. **Areas included:**
      a) Ulu Temburong National Park (NP),
      b) Sungai [=River] Ingei Conservation Forest in Belait district ([a] and [b] connected via Gunung [=Mount] Mulu NP and Gunung Buda NP and the surrounding matrix of forest reserves, state land and native customary land in Sarawak),

   c) Tasek [=Lake] Merimbun Heritage Park (at only 62 km², connected to [b] via Ladan Hills Forest Reserve (FR) in Brunei),
   d) Bukit [=Hill] Teraja Protection Forest in Belait district,
   e) Ulu [=headwaters] Mendaram Conservation Area (at only 78 km², it has already been proposed to be connected to [d] in Labi area of Belait district).

   ii. **Habitat types:** wetlands* [b, c, e]; transitional heath forest (kerangas) [b]; lowland forest [a, c, d]; upland forest [a, b]; montane forest [a].

   * habitat type 'wetland' can include peat swamp forest, freshwater swamp forest, mangroves or forested areas around lakes and could include any of these classes, or a combination.

   iii. **BCS priority species (globally threatened and Near Threatened species as per Wilting et al., 2016: Table 1) predicted to occur:** binturong, otter civet, Hose's civet, banded civet, collared mongoose, bay cat, Sunda clouded leopard, marbled cat, flat-headed cat.

   iv. **BCS priority species with confirmed records from BCS*:** otter civet, Hose's civet, marbled cat, flat-headed cat.

   * Records which satisfied the criteria for the BCS Database. Internet and press reports which could not be verified were excluded. From some regions, including Brunei, very few records were provided for the Borneo Carnivore Database. Hence, the number of species is much lower, although it is known that more species, such as the Sunda clouded leopard, occur in the HoB part of Brunei. A low number here, therefore, does not necessarily indicate a low richness of threatened carnivores; rather, it suggests insufficient survey effort and reporting.

   v. **Threats:** illegal logging; unsustainable logging; aloewood collection and hunting (often linked); encroachment from coastal development; drainage of the largest peat dome in Brunei, the Badas peat dome in Belait district, because of industrial infrastructure such as pipelines and road maintenance, resulting in increased susceptibility to forest fires; paucity of PA rangers; lack of connectivity of PAs within the country or with protected areas in Sarawak; forests in potential natural corridors connecting protected areas are designated for development/logging.

   vi. **Conservation actions recommended:** increased enforcement (including patrolling); increased survey effort and systematic faunal surveys; establishment and enhancement of linkage between [c] and Ladan Hills FR as well as between [d] and [e], in addition to links with forested areas in Sarawak; extension of protected area boundaries to include buffer zones to protect core areas; sustainable forest management if new areas are opened for timber exploitation; restoration and rehabilitation of degraded peatlands.

**TEXT BOX 2: SARAWAK, MALAYSIA**

**General remarks.** Much of interior northern and central Sarawak was predicted to host carnivore assemblages of high species richness. These areas cover a mosaic of protected areas, logging concessions, plantations, state land and native customary land which comprise lowland forests, highland forests and the unusual habitat of highland swamp forests (in Paya Maga in northern Sarawak). For wetland species, the areas predicted to be most important stretch along the highly fragmented coastal forests, particularly in north-western Sarawak (No. 4), and to a lesser degree, parts of central (No. 3) and northern Sarawak (No. 2).

In terms of trans-boundary conservation of wildlife, Sarawak is poised to play a crucial role: it is the only region linked to all the other regions (except Central and South Kalimantan) within Borneo, and has sizeable tracts of little-encroached forest adjacent to state or international borders. In the north, Pulong Tau NP within the Kelabit Highlands and the matrix of surrounding logging concessions and native land is connected to the largest protected area on Borneo, the Kayan Mentarang NP in North Kalimantan, forming a huge trans-boundary complex within the Heart of Borneo (HoB). Likewise, the Batang Ai–Lanjak Entimau complex in the south is predicted to be an important conservation area for many carnivores and is connected to the Betung Kerihun NP in West Kalimantan, thereby forming the Transborder Rainforest Heritage of Borneo, proposed as the first ever trans-boundary UNESCO World Heritage Site and also part of the HoB.

A general concern for Sarawak is that a great proportion of the land (35%, Sarawak Forest Department, 2015) is designated as Permanent Forest Estate, that is, mainly for logging and some as tree plantations (but Petersen et al. (2015) gave different figures). However, only one logging concession (Anap Muput Forest Management Unit) is currently certified as sustainably managed by the Malaysian Timber Certification Scheme (MTCS) and – in contrast to other provinces on Borneo – no logging concessions have been certified by the Forest Stewardship Council (FSC). In priority carnivore landscapes where logging is carried out, broader application of sustainable forest management would benefit carnivore conservation. In addition to unsustainable logging practices, conversion of natural forest to tree plantations (acacia or eucalyptus) or oil palm plantations is a pre-eminent threat. The total area licensed for the establishment of planted forests (i.e., tree plantations) in Sarawak covers about 7% of the existing area of permanent forest estates (Sarawak Forest Department, 2015), situated mainly in the Planted Forest Zone in central Sarawak; within a Planted Forest concession, up to 20% can be further converted into one cycle of oil palm planting before reverting to tree plantation.

The landscape of Sarawak is set to be altered further by a series of large hydroelectric dams – some of them within or close to the HoB. The Baram dam alone, in northern Sarawak, is expected to inundate more than 400 km² of forest and to displace more than 20,000 indigenous people;

plans for its construction have been shelved pending further studies and consultations with relevant stakeholders (see Tawie, 2015). Although the consequences for carnivore conservation prospects are difficult to predict, it is likely that such dams will intensify shifting agriculture and indiscriminate hunting (particularly during the construction phase with the influx of external labour) in a shrinking habitat. Often, such massive development programmes act as a catalyst for further development and thus will increase fragmentation and degradation in Sarawak. The mere process of construction, particularly of powerline routes, can enhance access hugely to formerly remote areas, and the reservoirs improve boat access to large areas formerly accessible only on foot. This increases greatly the range of forest products that are economically viable for commercial extraction. The consequences of such dams, and the associated road networks, on the movement and dispersal patterns of carnivores are unexplored. It is therefore unclear whether they will hinder dispersal and gene flow of wildlife populations (see also Shirley & Kammen, 2015).

Many indigenous communities live in forested areas in Sarawak, whether in protected areas or forest reserves. These communities depend on wildlife for their protein and exercise native customary rights over the land. Any conservation initiative in priority areas in Sarawak needs to work with local communities to understand their use of forest resources and wildlife within and close to protected areas. Conservation initiatives should not seek to bar indigenous communities from hunting but rather, improve their sense of custodianship of the lands and the wildlife within.

**Conservation research priorities.**

A. Basic inventory surveys in the following areas: along the Sarawak–Sabah border such as Paya Maga, the northeastern highlands of Lawas including Kanaya FR, areas surrounding Long Lopeng, Long Semado and Long Merarap and the forests around the headwaters of the Sungai Tengoa and the Sungai Berayong; Bungo Range Nature Reserve along the southern Sarawak–West Kalimantan border; central Sarawak including the proposed Baleh NP and Hose–Laga NP, and surrounding logging concessions around the headwaters of the Sungai Baleh and Sungai Balui in the district of Kapit and Belaga, as well as the matrix of remnant peat swamp forest, logging concessions, plantations and native lands around the coastal districts of Mukah and Dalat, and further inland in Selangau, Julau, Kanowit and Song, especially near the Sarawak–Kalimantan border within the HoB.

B. Research in degraded and modified landscapes, particularly tree plantations (for example in the Central Sarawak Complex), to understand carnivore use of such altered and fragmented habitat.

C. Studies on the effects and extent of hunting, bush meat consumption and trade in wildlife and its derivatives.

D. Studies on the effects of dams and associated road networks and how they could potentially hinder movement and dispersal of carnivores.

**Priority conservation interventions.**

A. Conduct education, sensitisation and awareness programmes targeting local communities, timber camp workers and plantation workers on laws and ordinances pertinent to the protection of wildlife as well as on sustainability practices and the importance of biodiversity conservation.

B. Impress upon government authorities the need for strong, consistent, long-term commitment and political will to enforce wildlife protection laws and ordinances.

C. Recruit and train more rangers to conduct enforcement (including patrolling) exercises in areas that are prone to hunting and encroachment such as along the peripheries of protected areas, logging concessions and plantations and in areas adjacent to human settlements where access has become easier e.g. in Tanjung Datu NP, Similajau NP, Maludam NP and Samunsam Wildlife Sanctuary.

D. Increase dialogue between local government, conservationists and indigenous communities on issues pertaining to the construction of mega-dams. Depending on the scale of the expected biodiversity losses, other areas with good forests and rich biodiversity should be designated for conservation to compensate the expected biodiversity loss caused by the dams.

E. Prepare area-specific, holistic management plans for all priority carnivore areas (listed below) aiming to maintain, and where appropriate, recreate forest connectivity and sustainable use; encourage forest concession areas and plantations to incorporate conservation of key habitats and wildlife within their Forest Management Plan /Planted Forest Management Plans (the protected area network alone is likely to be too small to safeguard Sarawak's carnivore biodiversity).

**Priority carnivore landscapes.**
Common threats within the priority carnivore landscapes: illegal logging; unsustainable logging; hunting; infrastructure development (e.g., expansion of large scale plantations, dams); land-use change (including conversion); encroachment from shifting agriculture and expanding plantations.

Common conservation actions recommended within the priority carnivore landscapes: enforcement (including patrolling); awareness and sensitisation programmes for local communities, government, logging staff and plantation company staff on sustainability practices, biodiversity conservation and the importance of wetland conservation; working with local communities to understand their needs and use of land and wildlife close to and within protected areas; engagement with local government, communities, logging companies, plantation owners and other stakeholders on proper land-use planning and management to halt conversion and increase connectivity; ensuring only sustainable practices conducted within the matrix of timber concessions and plantations.

**1. Heart of Borneo** [17% under TPA; 18.7% under PA – see Table 1 for details on estimation]

  **i.** **Areas included:**

    a) The Kelabit Highlands, Tama Abu Range, Pulong Tau NP, and surrounding matrix of logging concessions, tree plantations, state land and native customary land that includes Paya Maga, Layun Forest Management Unit (FMU), Kubaan–Puak FMU, Sela'an Linau FMU, Apad Lunan FR, Linau Danum FR, and others,

    b) Gunung Mulu–Gunung Buda NPs and surrounding logging concessions, native lands and state lands,

    c) the proposed Baleh NP and surrounding logging concessions, tree plantations, native lands and state land along the headwaters of the Sungai Baleh and Sungai Balui,

    d) Batang Ai NP, Lanjak Entimau Wildlife Sanctuary and surrounding logging concessions, tree plantations, state land and native lands.

  **ii.** **Habitat types:** mainly highlands with swampy highlands in Paya Maga; some wetlands (see Brunei text box for definition) and lowland forest also in [c, d].

  **iii.** **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, Hose's civet, banded civet, collared mongoose, Bornean ferret badger.

  **iv** **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, Hose's civet, banded civet, collared mongoose.

  **v. Area-specific threats:** planned construction of a series of hydroelectric dams in [a, c] and unsustainable logging and expansion of large-scale plantations (mainly, but not restricted to [a, c]), resulting in fragmentation and low connectivity between individual units.

  **vi. Specific conservation actions recommended:** gazette the Baleh NP; establish corridors to increase connectivity between the (mainly) highland forests in [a, b] and also to connect to the lowlands and wetlands [mainly in c, d] and to Betung Kerihun NP in West Kalimantan through riparian forests within the surrounding logging concessions and plantations; increase survey effort in areas along the Sabah border; investigate the effects of logging on species presence and tolerance of different logging levels.

2. **Extended Baram Complex (proposed extension to the Heart of Borneo)** [5% under both TPA and PA – see Table 1 for details on estimation]

i.  **Areas included:**

a)  Usun Apau NP,

b)  Loagan Bunut NP,

c)  Dulit FR and surrounding matrix of logging concessions, plantations, state land and native customary land.

ii. **Habitat types:** mainly upland and some lowland forest; wetlands (see Brunei text box for definition) in [b].

iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, Hose's civet, banded civet, collared mongoose.

iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, Hose's civet, banded civet, collared mongoose.

v.  **Area-specific threats:** planned construction of a mega hydroelectric dam on the Sungai Baram (temporarily shelved; Tawie, 2015) and unsustainable logging and expanding oil palm plantations resulting in fragmentation and low connectivity between individual units, especially with the isolated [b]; pollution of wetlands in [b] from upstream oil palm plantations.

vi. **Specific conservation actions recommended:** establish corridors to increase connectivity with the highland forests in the HoB and to connect to wetlands in [b] through riparian forests within the surrounding logging concessions and plantations; explore the possibility of habitat restoration and reforestation programmes on degraded lands, particularly surrounding the Loagan Bunut wetlands.

3. **Central Sarawak Complex** [8% under TPA; 15% under PA – see Table 1 for details on estimation]

i.  **Areas included:**

a)  Anap Muput FMU,

b)  Pelagus NP,

c)  the proposed Bukit Sarang NP,

d)  Bukit Kana NP,

e)  northern parts of the proposed Hose Mountains–Batu Laga complex,

f)  matrix of logging concessions, plantations (both wood and oil palm), native land and state land around the areas of Selangau, Tatau, Pelagus, Kapit and Song.

ii. **Habitat types:** wetlands (see Brunei text box for definition), lowland and upland forest.

iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

v.  **Area-specific threats:** planned construction of a series of hydroelectric dams on the tributaries of the Sungai Rajang and expansion of large scale plantations, resulting in fragmentation and low connectivity between individual units; mining (both legal and illegal).

vi. **Specific conservation actions recommended:** establish and enhance connectivity through riparian forests in surrounding plantations and forest reserves within the HoB; gazette the Bukit Sarang NP and the Hose Mountains–Batu Laga complex; explore the possibility of habitat restoration and reforestation on degraded land, particularly in areas connecting proposed and existing national parks such as along the Sungai Rajang from Kapit to Belaga; increase survey effort and investigate the effects on carnivores of wood plantations and the tolerance of carnivores to fragmentation.

4. **Rajang Delta–Saribas–Tanjung Datu Complex** [39% under both TPA and PA – see Table 1 for details on estimation]

i.  **Areas included:**

a)  the proposed Batang Lassa NP,

b)  Bruit–Patok NP,

c)  Rajang Mangroves NP and surrounding matrix of forest reserves, oil palm plantations, native customary land and state land,

d)  Tanjung Datu NP,

e)  Gunung Pueh NP,

f)  Samunsam Wildlife Sanctuary,

g)  Kubah NP,

h)  Kuching Wetlands NP and Ramsar site,

i)  Bako NP,

j)  Sedilu NP,

k)  Ulu Sebuyau NP,

l)  Gunung Lesung NP,

m) Maludam NP and the intervening matrix of native customary land, state land, logging concessions and oil palm plantations

ii. **Habitat types:** wetlands (see Brunei text box for definition) and lowland forest; some upland forest in [e].

iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled

cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

iv. **Area-specific threats:** land-use change (including conversion to aquaculture); fragmentation and very low connectivity between individual units resulting from human development (urban and rural), plantations and forest concessions; construction of flood mitigation channel in [h]; potential of future sedimentation and influx of freshwater into the mangroves of [h]; few carnivore-based surveys carried out; peat dome collapse because of the establishment of drainage canals from surrounding oil palm plantations and illegal logging.

v. **Specific conservation actions recommended:** establish and enhance connectivity through riparian forests in surrounding plantations and forest reserves and explore the possibility of habitat restoration and reforestation on degraded land; conduct systematic carnivore-based and faunal surveys of other taxa.

**TEXT BOX 3: SABAH, MALAYSIA**

**General remarks.** Sabah is the most intensively surveyed of all geopolitical regions on Borneo, resulting in the highest number of occurrence records for almost all carnivores. Despite the large number of local and international researchers working in the state, some areas, particularly those north of the East–West Sabah highway, have not been surveyed. In terms of forestry and wildlife conservation, most areas within Sabah are among the better-managed areas of Borneo. Nevertheless, Sabah experienced the highest deforestation rates on Borneo within the last 40 years and has lost almost 40% of its initial forest cover, mainly because of the conversion of natural forest to oil palm plantations (Gaveau et al., 2014). In addition to these converted areas, a high proportion of the state has been selectively logged (Gaveau et al., 2014). A number of intensive studies in Sabah, however, revealed that in many of these selectively logged forests, a high diversity of Bornean carnivores, including highly threatened species, persists. Hence, large areas of south to central Sabah, which were previously selectively logged, were predicted to support high carnivore species richness.

As in the other parts of Borneo, maintaining connectivity between key carnivore landscapes is of great importance for the conservation of carnivores in Sabah. Three recent initiatives and proposals highlight this need. First, parts of some commercial forest reserves were reclassified as totally protected areas in central Sabah, connecting the already existing totally protected areas of Danum Valley, Maliau Basin and Imbak Canyon; second, the recent proposal to link Kinabalu Park and Crocker Range Park via the Kinabalu Ecological Link (Kinabalu Eco-Linc); and third, the proposed linking of Tabin Wildlife Reserve in the Dent Peninsula to the Lower Kinabatangan–Segama Wetlands Ramsar site via the Kulamba Wildlife Reserve. The Kinabalu Eco-Linc is of particular significance for highland specialists, especially the Bornean ferret badger, which has been recorded only from this massif, whereas the Tabin–Kulamba–Kinabatangan Corridor will create a large contiguous complex of protected areas of particular value to highly threatened wetland carnivores. Ideally, these initiatives should not be tempered with the degazettement of existing protected areas for oil palm and tree plantations because it risks undermining the perceived permanence of other protected areas. This process, however, has begun already in some areas e.g. south-east of the Maliau Basin.

In Sabah, fewer indigenous peoples live in the forests and depend on wildlife and forest products than in other parts of Borneo. Subsequently, although subsistence hunting is still a threat in Sabah, hunting levels are generally lower than in other parts of Borneo. Sport hunting and poaching for the illegal trade in wildlife and its derivatives is, however, on the increase in Sabah (see e.g., Daily Express, 2015a, b; The Star Online 2015). Hence, enforcement (including patrolling) coupled with monitoring programmes are much needed in Sabah.

**Conservation research priorities.**

A. Intensified research in logging concessions, preferably those applying a range of logging strategies, as well as in non-forest landscapes such as monoculture plantations, to improve understanding of use and tolerance level of carnivores to modified, degraded and fragmented landscapes. Such research should be incorporated into the management plans of forest concessions and plantations to ensure long-term monitoring and thereby increase sustainability.

B. In-depth ecological studies on highland species with a focus on the locally endemic Bornean ferret badger in the Crocker Range Park, Kinabalu Park and the Eco-Linc project.

C. Inventory surveys along the Sarawak and North Kalimantan borders, in areas north of the East–West Sabah highway, and in the coastal wetlands, the latter to identify currently unknown populations of the highly threatened wetland carnivores. (The central Sabah forest complex, Tabin Wildlife Reserve and Kinabatangan Wildlife Sanctuary are already well surveyed.)

D. Research to quantify illegal wildlife trade within Sabah. Despite several confiscations of illegally collected or traded wildlife in the last few years, the degree of illegal hunting and trade is unknown. It is thus uncertain how imminent the threat is for wildlife populations in Sabah.

E. A centralised database of species records within the Sabah Biodiversity Centre (SBC; through which all research projects seek approval) to which all scientists and other interested parties could contribute their data. Such a database would be an extremely valuable resource for conservation planning and help to direct research in the state.

**Priority conservation interventions.**

A. Enforce laws (including through patrolling) in areas prone to hunting and encroachment such as along the peripheries of parks, and in areas adjacent to human settlements and plantations where access has become easier.

B. Build capacity and train local authorities in standardised enforcement tools to increase the efficiency of enforcement (including patrolling).

C. Raise conservation awareness of local communities, timber camp workers and forest managers, plantation workers and managers, and local government, on sustainability practices and wildlife protection laws and ordinances.

D. Create wildlife corridors connecting adjacent protected areas and existing forest blocks under logging operations and/or plantations.

**Priority carnivore landscapes.**

Common threats within the priority carnivore landscapes: illegal logging; aloewood collection and hunting (often linked); habitat degradation through unsustainable logging and plantation practices; pollution (e.g. pesticide run-off) from oil palm plantations and palm oil mills.

Common conservation actions recommended at all priority conservation areas: education and awareness programmes and capacity building for plantation managers and staff, local communities and local government in sustainability practices, biodiversity conservation and the importance of wetland conservation; working with local communities to understand their needs and use of land and wildlife close to and within park boundaries.

1. **Heart of Borneo** [26.9% under TPA; 27.3% under PA – see Table 1 for details on estimation]

    i. **Areas included:**
        a) Kinabalu Park,
        b) Trus Madi FR,
        c) Crocker Range Park,
        d) Sipitang–Ulu Padas FR,
        e) Maligan Virgin Jungle Reserve,
        f) Gunung Lumaku Protection Forest Reserve,
        g) Danum Valley Conservation Area,
        h) surrounding plantations and forest reserves, some of which participate in certification schemes such as Forest Stewardship Council FSC (e.g. Deramakot, Tangkulap, Ulu Segama and Malua FRs) and some which do not (e.g. Segaliud Lokan FR),
        i) Imbak Canyon Conservation Area,
        j) Maliau Basin Conservation Area.

    ii. **Habitat types:** lowland forest; wetlands (see Brunei text box for definition) [in g, h]; highlands in [a, b, c, d, e, f, i, j].

    iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, Hose's civet, banded civet, collared mongoose, Bornean ferret badger.

    iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, Hose's civet, banded civet, collared mongoose, Bornean ferret badger.

    v. **Area-specific threats:** habitat degradation through unsustainable logging resulting in inadequate connectivity between individual units; in some areas, hunting and collection of forest products by local communities and plantation workers.

    vi. **Specific conservation actions recommended:** enforcement (including patrolling); development of Forest Management Plans for forest concessions including High Conservation Value Forest identification and management planning; systematic surveys particularly in [b]; maintenance and enhancement of connectivity between individual units and among trans-boundary units, e.g. between [d & e] with Paya Maga and Kanaya FR in Sarawak.

5. **Tabin–Kinabatangan Wetlands** [66% under both TPA and PA – see Table 1 for details on estimation]

    i. **Areas included:**
        a) Tabin Wildlife Reserve,
        b) Kulamba Wildlife Reserve,
        c) Kinabatangan Wildlife Sanctuary,
        d) Kuala Maruap FR.

    ii. **Habitat types:** mainly wetlands and lowland forest.

    iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

    iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

    v. **Area-specific threats:** fragmentation and little connectivity between individual units; forest fires; encroachment by local communities and oil palm plantations resulting in further habitat loss; lack of capacity for effective law enforcement.

    vi. **Specific conservation actions recommended:** establish and enhance connectivity through riparian forests (particularly along the Sungai Kinabatangan and Sungai Segama) [This connectivity can be realised only in close collaboration with the oil palm industry because wildlife corridors are needed through the restoration of riparian forests within existing plantations – there is potential to connect this priority area along the Sungai Kinabatangan to the HoB]; capacity building and training of rangers and honorary wildlife wardens to conduct enforcement (including patrolling work).

**TEXT BOX 4: KALIMANTAN, INDONESIA**

**General remarks.** There are now five provinces in Kalimantan (the fifth, North Kalimantan, formed in October 2012, was previously part of East Kalimantan), the Indonesian part of Borneo. It covers approximately two-thirds of the island. A large proportion of Kalimantan forests remains either unprotected or is managed inadequately with a high risk of degradation, mainly from economic development pressures (e.g., Gaveau et al., 2014; Runting et al., 2015). Within the last four decades, Kalimantan experienced the second-highest deforestation rate on Borneo, losing over 30% of its initial forest cover, with many areas converted into oil palm plantations (Gaveau et al., 2014). New development projects such as the proposed Trans Kalimantan highway, which would connect the coast of North Kalimantan to the interior highlands through Kayan Mentarang NP to the coast of Sarawak and eventually extend to West Kalimantan, are likely to act as a catalyst for further forest losses. Such development projects are likely also to increase landscape fragmentation and improve access to previously isolated areas, thereby escalating levels of hunting and encroachment.

Apart from forest clearance, degradation of forests is a major threat in Kalimantan. Almost 25% of forests were selectively logged within the last 40 years (Gaveau et al., 2014). In many areas, this logging was conducted unsustainably and/or illegally (Smith et al., 2003). Other serious threats include hunting for bush meat and the illegal wildlife trade, and the lack of capacity and political will to enforce wildlife conservation laws. Furthermore, in many areas, local communities expand their land holdings rapidly, leading to further encroachment for agriculture. In some parts of Kalimantan, mining and pollution associated with it is another threat to wildlife populations.

A conservation concern more severe in Kalimantan than in northern Borneo is forest fires. These are usually started by small-scale farmers and large plantations to open up land for agriculture. The situation is exacerbated by the drainage of peat swamp forests because of the construction of canals to facilitate the expansion of oil palm plantations and logging – the dried up peat swamps are highly susceptible to fires. Areas prone to forest fires include the southern coasts of Central Kalimantan, scattered localities in the south-east and east coast of East Kalimantan (in 1997–1998, 5.2 million hectares of land were affected by fires in East Kalimantan [today's East Kalimantan + North Kalimantan] alone; Siegert et al., 2001), and the south and central west coast of West Kalimantan, corresponding to the distribution of peat swamp forests; wetland specialist carnivores will suffer most from fires in these habitats. At the time of going to press, researchers' data on the extent of the extensive 2015 burning event were yet to be released.

Despite these threats and habitat losses, many parts of Kalimantan were predicted to harbour high carnivore species richness, including much of North Kalimantan, northern East Kalimantan, the Schwaner–Müller range and surrounding areas in the Heart of Borneo (HoB); for wetland species, the most important areas are scattered along the coasts of North, Central and West Kalimantan as well as along the major rivers, the Kapuas, Mahakam and Barito. The habitat suitability predictions were generally lower than in north Bornean states. This was especially true for the provinces of West and South Kalimantan. Kalimantan is overall less well surveyed than is the rest of Borneo. This lower survey effort and correspondingly fewer occurrence records certainly resulted also in lower predictions, despite efforts to correct for uneven sampling across Borneo (Kramer-Schadt et al., 2016). The lack of records biased predictions most strongly in regions with bioclimatic conditions different from the rest of Borneo (e.g., south-eastern Kalimantan; Kramer-Schadt et al., 2016: Fig. 3A). More surveys could evaluate whether the low predicted habitat suitability reflects methodological issues, climatic distinctiveness or because large areas have been transformed into unsuitable land cover such as oil palm plantations (see Kramer-Schadt et al., 2016: Fig. 3A).

**Conservation research priorities.**

A.  Inventory surveys where current carnivore occurrence data are sparse. Of particular importance are surveys in South Kalimantan, especially the Pergunungan [=mountain range of] Meratus and its surrounding areas; in Central Kalimantan, the Arabela–Schwaner landscape; in West Kalimantan, Gunung Niut–Penrisen Nature Reserve and surrounding areas, Bukit Rongga Protection Forest and surrounding areas, and much of Betung Kerihun NP; in East Kalimantan, the proposed Long Bangun Nature Reserve and surrounding matrix of logging concessions, native lands and plantations as well as the Mangkalihat–Sangkulirang peninsula; and in North Kalimantan, regions along the Sabah border such as Buatan–Loetak–Agisan areas, the north-eastern coast including the proposed Sebuku–Sembakung NPs and surrounding areas and parts of the proposed Sungai Kayan NP, including the surrounding matrix of forest reserves, native lands and plantations.

B.  Research on the adaptability of species to habitat degradation and fragmentation. A better understanding of the use of these modified landscapes is essential to improve the sustainability of management and to incorporate areas under cultivation and development into conservation measures.

C.  Studies on the effects and extent of hunting and trade in wildlife and derivatives.

D.  Studies on the effects of roads and human settlements in terms of their potential hindrance of movement and dispersal of carnivores.

E.  Studies on the impact of fire on the survival and ecology of carnivores and their prey species.

**Priority conservation interventions.**

A.  Establish and maintain connectivity between fragmented forests to create larger areas within and between

provinces (as in Brunei, Sarawak and Sabah, the main priority). Examples are: an inter-provincial conservation area between the Bukit Baka–Bukit Raya NP, adjacent timber concession areas (including the FSC-certified SBK Seruyan–Katingan FR, all in the southwestern portion of Heart of Borneo (No. 1)) and timber concessions within the Arabela–Schwaner Landscape (No. 9) in Central Kalimantan, including the Bukit Perai–Bukit Rongga FRs in West Kalimantan (also No. 9). This area is important not just to ensure the long-term conservation of carnivores, but also of Bornean Orang-utan *Pongo pygmaeus* and other species (e.g., Struebig et al., 2015b).

B. Create awareness among local stakeholders and authorities on the importance of wildlife and forest conservation and on a more sustainable mode of development. Strong governmental support and political will is required to address the major conservation concerns in Kalimantan.

C. Build capacity and train local authorities in standardised enforcement tools such as SMART (Spatial Monitoring and Reporting Tool), to increase the efficiency of law enforcement (including patrolling) to curb illegal hunting, illegal logging, encroachment, the setting of fires and the draining of peat swamp forests. Also, local authorities need to increase their capacities for law enforcement; at present, teams are notoriously understaffed.

D. Build conservation awareness and capacity among local communities, timber camp workers and forest managers, plantation workers and managers, and local government, on sustainability practices, particularly in High Conservation Value Forest planning and management and wildlife protection laws and ordinances.

E. Work with local communities to understand their needs and use of land and wildlife, and to develop management plans.

**Priority carnivore landscapes.**
Common threats within priority carnivore landscapes: illegal logging; unsustainable logging; hunting; fragmentation; encroachment from shifting agriculture; low capacity among forest managers and local authorities to enforce wildlife laws.

Common conservation actions recommended within the priority carnivore landscapes: enforcement (including patrolling); awareness, education and sensitisation programmes for local communities, local government, and other stakeholders (e.g., logging, plantation and mining company staff) on sustainability practices, High Conservation Value Forest identification and management planning, wildlife laws and ordinances, biodiversity conservation and on the importance of wetland conservation; working with local communities to understand their needs and use of land and wildlife close to and within protected areas; engagement with local government, local communities and other stakeholders (e.g., logging, plantation and mining company staff) on proper land-use planning and management to halt conversion and increase connectivity; insist that only sustainable practices are conducted within the matrix of timber concessions and/ or plantations; systematic surveys and long-term monitoring.

**Priority carnivore landscapes (South Kalimantan, Indonesia)**

6. **Pergunungan Meratus** [4% under TPA; 54% under PA – see Table 1 for details on estimation]

    **i. Areas included:** Meratus Hulu Barabai Nature Reserve and forests along the mountain chain which include the surrounding tree plantations and mining concessions.

    **ii. Habitat types:** mainly highlands.

    **iii. BCS priority species** (see Brunei text box for definition) **predicted to occur:** marbled cat, binturong, banded civet, collared mongoose and to a lesser extent, flat-headed cat, bay cat, Sunda clouded leopard and otter civet.

    **iv. BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** none.

    **v. Area-specific threats:** isolated; (apparently) no management plan in place; mining; forest fires; lack of awareness amongst forest managers, local government and local communities on the importance of the area being actively protected.

    **vi. Specific conservation actions recommended:** most important are inventory wildlife surveys; Forest Management Plans for timber concessions.

**Priority carnivore landscapes (Central Kalimantan, Indonesia)**

1. **Heart of Borneo** [11.7% under TPA; 36.7% under PA – see Table 1 for details on estimation]

    **i. Areas included:**
    a) Bukit Baka–Bukit Raya NP and surrounding logging concessions, some of which participate in certification schemes such as Forest Stewardship Council FSC [e.g. Katingan–Seruyan Block],
    b) Bukit Raya Nature Reserve (proposed extension of [a]),
    c) the proposed Bukit Batikap I, II and III Nature Reserve,
    d) Bukit Sepat Huang Nature Reserve (at the border of Central and East Kalimantan).

    **ii. Habitat types:** mainly lowland and upland forest.

    **iii. BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose

    **iv. BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

    **v. Area-specific threats:** illegal mining and associated pollution; proposed nature reserves not yet confirmed;

uncertified logging concessions do not follow sustainable principles.

**vi. Specific conservation actions recommended:** gazette the Bukit Batikap I, II, III Nature Reserve; regular contact and sensitisation programmes for forest managers yet to engage in sustainability practices and the forest certification process; establish and enhance corridor connectivity between logging concessions and protected areas within the complex, and between the protected areas in different provinces that make up this forest complex and the larger HoB; pursue proposals for Ecosystem Restoration Concession (ERC) licence for REDD and ecotourism projects that involve local communities with appropriate sustainable management plans which prioritise conservation actions and ecological linkages.

7. **Sabangau Complex** [54% under TPA; 56% under PA – see Table 1 for details on estimation]

   **i. Areas included:**
   a) Sabangau NP,
   b) Mungku Baru and Bawan Forest,
   c) parts of the surrounding Mentaya–Katingan and Kalampangan peat swamp forests.

   **ii. Habitat types:** mainly wetlands (see Brunei text box for definition); lowland forest and tropical heath forest (kerangas) in [b].

   **iii. BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, Sunda clouded leopard, otter civet, collared mongoose.

   **iv. BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, marbled cat, Sunda clouded leopard, otter civet, collared mongoose; since this modelling study, binturong also recorded.

   **v. Area-specific threats:** illegal mining and associated pollution; peat dome collapse because of the establishment of drainage canals from surrounding oil palm plantations and illegal logging leading to increased susceptibility to forest fires; low political will to protect the park; encroachment from surrounding oil palm plantations; low connectivity; land-use change (including conversion).

   **vi. Specific conservation actions recommended:** block drainage channels in swamp forests; prevent forest fires; establish and enhance connectivity through riparian forests in surrounding plantations and forest reserves; pursue REDD+ activities under the Kalimantan Forests and Climate Partnership and the Katingan Peatland Restoration project; pursue proposals for issuance of ERC licenses and/or Hutan Desa (Village/Community Forest) status outside protected areas to encourage the participation of local communities in rehabilitation programmes with

appropriate sustainable management plans, prioritising conservation actions and ecological linkages.

8. **Tanjung Puting NP** [59% under TPA; 67% under PA – see Table 1 for details on estimation]

   **i. Areas included:** Tanjung Puting NP and surrounding areas.

   **ii. Habitat types:** Wetlands (see Brunei text box for definition) and lowland forest.

   **iii. BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, Sunda clouded leopard, binturong, otter civet, banded civet.

   **iv. BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, binturong.

   **v. Area-specific threats:** illegal mining and associated pollution; peat dome collapse because of the establishment of drainage canals from surrounding oil palm plantations and illegal logging leading to increased susceptibility to forest fires; lack of political will to protect the park; encroachment from surrounding oil palm plantations; low connectivity; land-use change (including conversion); limited capacity amongst park staff for conservation management.

   **vi. Specific conservation actions recommended:** block drainage channels in swamp forests; prevent forest fires; establish and enhance connectivity through riparian forests in surrounding plantations and forest reserves; improve boundary demarcation to facilitate patrolling of park boundaries, and capacity building and training of park authorities to conduct enforcement (including patrolling work); pursue the Rimba Raya REDD+ project with a focus on community benefits and involvement via proposals for ERC licenses and/or Community Forest status with appropriate sustainable management plans prioritising conservation actions and ecological linkages.

9. **Arabela–Schwaner Landscape (proposed extension to Heart of Borneo)** [0% under TPA; 7% under PA – see Table 1 for details on estimation]

   **i. Areas included:** mainly logging concessions to the southeast of Bukit Baka–Bukit Raya NP, some of which participate in FSC certification schemes.

   **ii. Habitat types:** mainly lowland and upland forest.

   **iii. BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

   **iv. BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-

headed cat, banded civet, collared mongoose; since this modelling study, Hose's civet also recorded.

v. **Area-specific threats:** forest degradation through unsustainable logging and common threats as above for most priority carnivore landscapes in Kalimantan.

vi. **Specific conservation actions recommended:** regular contact and sensitisation programmes for forest managers yet to engage in sustainability practices and the forest certification process; maintain and enhance corridor connectivity between logging concessions and the HoB complex; pursue proposal for REDD+ projects with community participation to finance protection of High Conservation Value Areas (HCVAs) and important ecological corridors; pursue proposal for Village/Community Forest status and ERC license with appropriate sustainable management plans prioritising habitat restoration, conservation actions and ecological linkages.

**Priority conservation areas (West Kalimantan, Indonesia)**

1. **Heart of Borneo** [20.8% under TPA; 47.5% under PA – see Table 1 for details on estimation]

   i. **Areas included:**
      a) Bukit Batutenobang Protection Forest and surrounding mosaic of plantations, production and protection forests, some of which participate in certification schemes such as FSC,
      b) Danau Sentarum NP and surrounding oil palm plantations and production forests,
      c) Betung Kerihun NP and surrounding oil palm plantations and production forests.

   ii. **Habitat types:** lowland and highland forest [a, c]; wetlands in [b] (see Brunei text box for definition).

   iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

   iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated): flat-headed cat, marbled cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

   v. **Area-specific threats:** low awareness amongst local communities, logging and plantation company staff on sustainability and conservation of wetlands and wildlife; low connectivity between individual units because of, in part, surrounding oil palm plantations (mainly in [b]); forest degradation; encroachment from surrounding oil palm plantations; illegal mining, mainly in [c]; planned road construction along the West Kalimantan–Sarawak boundary in [c].

   vi. **Specific conservation actions recommended:** maintain and enhance corridor connectivity between [b] & [c] and Batang Ai–Lanjak Entimau complex

in Sarawak thereby enhancing the value of the Transborder Rainforest Heritage of Borneo, proposed as the first ever UNESCO Trans-boundary World Heritage Site; pursue REDD+ projects with community participation to finance protection of HCVAs and important ecological corridors (in [b]); pursue proposal for Village/Community Forest status and ERC license with appropriate sustainable management plans prioritising habitat restoration, conservation actions and ecological linkages (in [b]).

9. **Arabela–Schwaner Landscape (proposed extension to Heart of Borneo)** [17% under TPA; 18.7% under PA – see Table 1 for details on estimation]

   i. **Areas included:** Bukit Perai–Bukit Rongga Protection Forest blocks which consist of a mosaic of production and protection forests, some of which participate in certification schemes such as FSC.

   ii. **Habitat types:** lowland and highland forest.

   iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

   iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated): bay cat.

   v. **Area-specific threats:** mining; low awareness amongst local communities, logging and plantation company staff on sustainability and conservation of wildlife; low connectivity between individual units; forest degradation; encroachment from surrounding oil palm plantations.

   vi. **Specific conservation actions recommended:** maintain and enhance corridor connectivity between logging concessions and protected areas in the complex and also with the larger HoB; pursue REDD+ projects with community participation to finance protection of HCVAs and important ecological corridors; pursue proposal for Village/Community Forest status and ERC license with appropriate sustainable management plans prioritising habitat restoration, conservation actions and ecological linkages.

10. **West Kalimantan Western Wetland Complex** [16% under TPA; 30% under PA – see Table 1 for details on estimation]

   i. **Areas included:**
      a) Gunung Palung NP,
      b) Sungai Putri Forest Block in Ketapang district, comprising forested areas under diverse statuses such as Limited Production Forest, Convertible Production Forest, Permanent Production Forest, oil palm and tree plantations and community lands,
      c) Pulau Maya.

ii. **Habitat types:** mainly wetlands (see Brunei text box for definition); some lowland and upland forest in [a].

iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

v. **Area-specific threats:** encroachment from expanding plantations; low connectivity because of the expansion of oil palm plantations in surrounding forests; low political will to protect and engage in conservation efforts; construction of canal for transportation in [c]; peat drain leading to increased susceptibility to forest fires; no conservation management plan for [b & c]; displacement of local community farming.

vi. **Specific conservation actions recommended:** block draining of swamp forests; pursue proposal for Kubu Raya REDD+ projects and Payment for Environmental Services (PES) projects within concession borders and in community forest lands to finance protection of HCVAs and important ecological corridors; pursue proposal for ERC license and Village/ Community Forest status with appropriate sustainable management plans prioritising conservation actions and ecological linkages.

**Priority conservation areas (East Kalimantan, Indonesia)**

1. **Heart of Borneo** [0% under TPA; 36.9% under PA – see Table 1 for details on estimation]

    i. **Areas included:**

       a) Bukit Sepat Huang Nature Reserve (at the border of Central and East Kalimantan),

       b) the proposed Long Bangun Nature Reserve,

       c) the surrounding mosaic of plantations and logging concessions.

    ii. **Habitat types:** mainly lowland and upland forest with some wetlands (see Brunei text box for definition).

    iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

    iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** marbled cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

    v. **Area-specific threats:** the proposed Long Bangun Nature Reserve remains unprotected; forest degradation through unsustainable logging and other

common threats as listed above for most areas in Kalimantan.

    vi. **Specific conservation actions recommended:** gazette the Long Bangun Nature Reserve; support sustainable logging and plantation practises.

11. **Wehea–Mangkalihat–Sangkulirang Complex (proposed extension to the Heart of Borneo)** [0% under TPA; 11% under PA – see Table 1 for details on estimation]

    i. **Areas included:**

       a) Mangkalihat and Sangkulirang deltas and surrounding oil palm plantations,

       b) Mangkalihat–Sangkulirang Karst Mountains and surrounding timber concessions and plantations,

       c) Wehea Forest and surrounding logging concessions and plantations.

    ii. **Habitat types:** lowland and upland forest; karst mountains in [b].

    iii. **BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, Hose's civet, banded civet, collared mongoose.

    iv. **BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** marbled cat, Sunda clouded leopard, binturong, otter civet, banded civet.

    v. **Area-specific threats:** lack of awareness amongst local communities and government on the importance of conserving biodiversity; cement mining/unregulated mining in [b]; forest fires; insufficient legal protection.

    vi. **Specific conservation actions recommended:** engagement with local government, local communities and other stakeholders for land-use management appropriate to establish and enhance connectivity with the proposed Sungai Kayan NP in North Kalimantan and the greater HoB complex; improved legislation for protection of karst mountains, followed by enforcement (including patrolling).

**Priority conservation areas (North Kalimantan, Indonesia)**

1. **Heart of Borneo** [25.3% under TPA; 48.4% under PA – see Table 1 for details on estimation]

    i. **Areas included:**

       a) Kayan Mentarang NP, the Apo Kayan Highlands,

       b) the proposed Sungai Kayan NP and surrounding logging concessions,

       c) Malinau Basin.

    ii. **Habitat types:** mainly highlands; lowland forest in [c].

**iii. BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, Hose's civet, banded civet, collared mongoose.

**iv. BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, banded civet, collared mongoose.

**v. Area-specific threats:** road network connecting the Kalimantan coast to Kayan Mentarang NP and associated threats through increased accessibility; encroachment from surrounding oil palm and tree plantations; forest fires; mining; lack of political will to engage in conservation efforts.

**vi. Specific conservation actions recommended:** gazette Sungai Kayan NP; improve enforcement (including patrolling); maintain and enhance corridor connectivity, particularly between [a] and [c] which would not only connect lowland forest with that of the highlands, but also provide trans-boundary connectivity on a larger scale with Pulong Tau NP and the Kelabit Highlands in Sarawak.

**12. Sebuku–Sembakung Complex (proposed extension to the Heart of Borneo)** [0% under both TPA and PA – see Table 1 for details on estimation]

**i. Areas included:**

a) the proposed Sebuku–Sembakung NP,

b) surrounding forest concessions and oil palm plantations.

**ii. Habitat types:** mainly wetlands (see Brunei text box for definition) and some lowland forest.

**iii. BCS priority species** (see Brunei text box for definition) **predicted to occur:** flat-headed cat, marbled cat, bay cat, Sunda clouded leopard, binturong, otter civet, banded civet, collared mongoose.

**iv. BCS priority species with confirmed records from BCS** (see HoB [No. 1] in the Brunei text box for details on how confirmed species records are treated)**:** Sunda clouded leopard.

**v. Area-specific threats:** road development; encroachment from surrounding oil palm plantations; lack of political will to engage in conservation efforts; coal mining, both legal and illegal.

**vi. Specific conservation actions recommended:** gazette Sebuku–Sembakung NP; maintain and enhance connectivity to HoB by restoration of degraded habitat.

## ACKNOWLEDGEMENTS

## LITERATURE CITED

Ancrenaz M, Dabek L & O'Neil S (2007) The cost of exclusion: recognizing a role for local communities in biodiversity conservation. Plos Biology, 5(11): e289.

Balmford A & Whitten T (2003) Who should pay for tropical conservation, and how could the costs be met? Oryx, 37: 238–250.

Beck J, Schwanghart W, Khen CV & Holloway JD (2011) Predicting geometrid moth diversity in the Heart of Borneo. Insect Conservation and Diversity, 4: 173–183.

Belant JL & Wilting A (2013) Foreword: methods for detecting and surveying tropical carnivores. Raffles Bulletin of Zoology, Supplement 28: i–iii.

Belant JL, Hofer H & Wilting A (2013) Comparison of methods for detecting and surveying tropical carnivores. Raffles Bulletin of Zoology, Supplement 28: 109–113.

Belden G, Jukie A, Megom N & Unggang J (2014) Lowland records of masked palm civet *Paguma larvata* from Sarawak, Malaysian Borneo. Small Carnivore Conservation, 51: 56–58.

Bennett EL & Robinson JG (2000) Hunting of wildlife in tropical forests: implications for biodiversity and forest peoples. World Bank Biodiversity Series No.76. World Bank, Washington D.C., U.S.A., 42 pp.

Bennett EL & Gumal M (2001) The interrelationships of commercial logging, hunting, and wildlife in Sarawak. In: Fimbel RA, Grajal A & Robinson JG (eds.) The Cutting Edge: Conserving Wildlife in Logged Tropical Forest. Columbia University Press, New York, U.S.A. Pp. 359–374.

Bennett EL, Nyaoi AJ & Sompud J (2000) Saving Borneo's bacon: the sustainability of hunting. In: Robinson JG & Bennet EL (eds.) Hunting for Sustainability in Tropical Forests. Columbia University Press, New York, U.S.A. Pp. 305–324.

Bernard, H, Baking EL, Giordano AJ, Wearn OR & Abdul Hamid Ahmad (2014) Terrestrial mammal species richness and composition in three small forest patches within an oil palm landscape in Sabah, Malaysian Borneo. Mammal Study, 39: 141–154.

Brickle NW, Eaton JA & Rheindt FE (2010) A rapid bird survey of the Menyapa mountains, East Kalimantan, Indonesia. Forktail, 26: 31–41.

Brodie J & Giordano AJ (2012) Density of the Vulnerable Sunda clouded leopard *Neofelis diardi* in a protected area in Sabah, Malaysian Borneo. Oryx, 46: 427–430.

Castilhos ZC, Rodrigues-Filho S, Rodrigues APC, Villas-Bôas RC, Siegel S, Veiga MM & Beinhoff C (2006) Mercury contamination in fish from gold mining areas in Indonesia and human health risk assessment. Science of the Total Environment, 368: 320–325.

Cheyne SM & Macdonald DW (2011) Wild felid diversity and activity patterns in Sabangau peat-swamp forest, Indonesian Borneo. Oryx, 45: 119–124.

Cheyne SM, Mohamed A, Hearn AJ, Ross J, Samejima H, Heydon M, Augeri DM, van Berkel T, Boonratana R, Fredriksson G, Hon J, Marshall AJ, Macdonald DW, Belant JL, Kramer-Schadt S & Wilting A (2016) Predicted distribution of the otter civet *Cynogale bennettii* (Mammalia: Carnivora: Viverridae) on Borneo. Raffles Bulletin of Zoology, Supplement 33: 126–131.

Chutipong W, Tantipisanuh N, Ngoprasert D, Lynam AJ, Steinmetz R, Jenks KE, Grassman Jr LI, Tewes M, Kitamura S, Baker MC, McShea W, Bhumpakphan N, Sukmasuang R, Gale GA, Harich FK, Treydte AC, Cutter P, Cutter PB, Suwanrat S, Siripattaranukul K, Hala-Bala Wildlife Research Station, Wildlife Research Division & Duckworth JW (2014) Current distribution and conservation status of small carnivores in Thailand: a baseline review. Small Carnivore Conservation, 51: 96–136.

Corlett R (2007) The impact of hunting on the mammalian fauna of tropical Asian forests. Biotropica, 39: 292–303.

Coudrat CNZ, Nanthavong C, Sayavong S, Johnson A, Johnston JB & Robichaud WG (2014a) Conservation importance of Nakai–Nam Theun National Protected Area, Laos, for small carnivores based on camera trap data. Raffles Bulletin of Zoology, 62: 31–49.

Coudrat CNZ, Nanthavong C, Sayavong S, Johnson A, Johnston JB & Robichaud WG (2014b) Non-*Panthera* cats in Nakai–Nam Theun National Protected Area, Lao PDR. Cat News, Special Issue 8: 45–52.

Crees JJ, Collins AC, Stephenson PJ, Meredith HMR, Young RP, Howe C, Stanley Price MR & Turvey ST (2015) A comparative approach to assess the drivers of success in mammalian conservation recovery programs. Conservation Biology, doi: 10.1111/cobi.12652.

Daily Express (2015a) Endangered wildlife openly traded on the internet. http://www.dailyexpress.com.my/news.cfm?NewsID=102004 (Accessed 15 October 2015).

Daily Express (2015b) Explosion of illicit wildlife trafficking most serious threats. http://www.dailyexpress.com.my/news.cfm?NewsID=98581 (Accessed 15 October 2015).

Davis JT, Mengersen K, Abram N, Ancrenaz M, Wells JA & Meijaard E (2013) It's not just conflict that motivates killing of orangutans. PLoS One, 8(10): e75373.

D'Cruze N & Macdonald DW (2015) Clouded in mystery: the global trade in clouded leopards. Biodiversity and Conservation, 24: 3505–3526.

de Bruyn M, Stelbrink B, Morley RJ, Hall R, Carvalho GR, Cannon CH, van den Bergh G, Meijaard E, Metcalfe I, Boitani L, Maiorano L, Shoup R & von Rintelen T (2014) Borneo and Indochina are major evolutionary hotspots for Southeast Asian Biodiversity. Systematic Biology, 63: 879–901.

Di Marco M, Boitani L, Mallon D, Hoffman M, Iacucci A, Meijaard E, Visconti P, Schipper J & Rondinini C (2014) A retrospective evaluation of the global decline of carnivores and ungulates. Conservation Biology, 28: 1109–1118.

Dudley RG (2009) The fishery of Danau Sentarum. Borneo Research Bulletin, 31: 261–306.

Fitzherbert EB, Struebig MJ, Morel A, Danielsen F, Brühl CA, Donald PF & Phalan B (2008) How will oil palm expansion affect biodiversity? Trends in Ecology and Evolution, 23: 538–545.

Fredriksson G, Steinmetz R, Wong S & Garshelis D (IUCN SSC Bear Specialist Group) (2008) *Helarctos malayanus*. In IUCN Red List of Threatened Species. www.iucnredlist.org/details/9760/0 (Accessed 15 October 2015).

Gaveau DLA, Kshatriya M, Sheil D, Sloan S, Wich S, Ancrenaz M, Hansen M, Broich M, Molidena E, Wijaya A, Guariguata MR, Pacheco P, Potapov P, Turubanova S & Meijaard E (2013) Reconciling forest conservation and logging in Indonesian Borneo. PLoS One, 8(8): e69887.

Gaveau DLA, Sloan S, Molidena E, Yaen H, Sheil D, Abram NK, Ancrenaz M, Nasi R, Quinones M, Wielaard N & Meijaard E (2014) Four decades of forest persistence, clearance and logging on Borneo. PLoS One, 9(7): e101654.

Groves CR, Jensen DB, Valutis LL, Redford KH, Shaffer ML, Scott JM, Baumgartner JV, Higgins JV, Beck MW & Anderson MG (2002) Planning for biodiversity conservation: putting conservation science in practice. Bioscience, 52: 499–512.

Hidayat F (2015) Three arrested for killing protected Sun Bear. Tempo. co. http://en.tempo.co/read/news/2015/09/28/055704357/Three-Arrested-For-Killing-Protected-Sun-Bear (Accessed 15 November 2015).

Hoffman M, Belant JL, Chanson JS, Cox NA, Lamoreux J, Rodrigues ASL, Schipper J & Stuart SN (2011) The changing fates of the world's mammals. Philosophical Transactions of the Royal Society B, 366: 2598–2610.

Hon J, Hearn AJ, Ross J, Mohamed A, Alfred R, Samejima H, Cheyne SM, Semiadi G, Rustam, Boonratana R, Fredriksson G, Mathai J, Lim NTL, Marshall AJ, Macdonald DW, Belant JL, Kramer-Schadt S & Wilting A (2016) Predicted distribution of the collared mongoose *Herpestes semitorquatus* (Mammalia: Carnivora: Herpestidae) in Borneo. Raffles Bulletin of Zoology, Supplement 33: 142–148.

IUCN (2015) IUCN Red List of Threatened Species. Version 2015.3 http://www.iucnredlist.org. (Accessed 13 July 2015).

Kramer-Schadt S, Reinfelder V, Niedballa J, Lindenborn J, Stillfried M, Heckmann I & Wilting A (2016) The Borneo Carnivore Database and the application of predictive distribution modelling. Raffles Bulletin of Zoology, Supplement 33: 18–41.

Lajiun, J (2015) Illegal wildlife trade via social media, Borneo Post Online. http://www.theborneopost.com/2015/08/04/illegal-wildlife-trade-via-social-media/ (Accessed 15 November 2015).

Leong KH, Tan LLB & Mustafa AM (2007) Contamination levels of selected organochlorine and organophosphate pesticides in the Selangor River, Malaysia between 2002 and 2003. Chemosphere, 66: 1153–1159.

Linkie M, Martyr DJ, Harihar A, Risdianto D, Nugraha RT, Maryati, Leader-Williams N & Wong W-M (2015) Safeguarding Sumatran Tigers: evaluating effectiveness of law enforcement patrols and local informant networks. Journal of Applied Ecology, 52: 851–860.

Lynam AJ, Saw Tun Khaing & Khin Maung Zaw (2006) Developing a national Tiger action plan for the Union of Myanmar. Environmental Management, 37: 30–39.

MacMillan DC & Nguyen QA (2013) Factors influencing the illegal harvest of wildlife by trapping and snaring among the Katu ethnic group in Vietnam. Oryx, 48: 304–312.

Margules CR & Pressey RL (2000) Systematic conservation planning. Nature, 405: 243–253.

Mathai J, Duckworth JW, Wilting A, Ross J, Brodie J, Hon J, Holden J, Hearn A & Gemita A (2015a) *Herpestes semitorquatus*. In IUCN Red List of Threatened Species. www.iucnredlist.org/details/41616/0 (Accessed 20 November 2015).

Mathai J, Niedballa J, Sollmann R, Kramer-Schadt S & Wilting A (2015b) Understanding Borneo's elusive Hose's civet – factors determining fine-scale occupancy and refuge identification using climate and land-cover change projections. In: Schumann A, Fickel J & Hofer H (eds.) 10th International Conference on Behaviour, Physiology and Genetics of Wildlife. Leibniz Institute for Zoo and Wildlife Research, Berlin, Germany, p. 127.

Mathai J, Brodie J, Giordano AJ, Alfred R, Belant JL, Kramer-Schadt S & Wilting A (2016) Predicted distribution of Hose's civet *Diplogale hosei* (Mammalia: Carnivora: Viverridae) on Borneo. Raffles Bulletin of Zoology, Supplement 33: 118–125.

McCarthy J & Zen Z (2010) Regulating the oil-palm boom: assessing the effectiveness of environmental governance approaches to agro-industrial pollution in Indonesia. Law & Policy, 32: 153–179.

Meijaard E (2014) A review of historical habitat and threats of small-clawed otter on Java. IUCN Otter Specialist Group Bulletin, 31: 40–44.

Meijaard E (2015) Indonesia's fire crisis: the biggest environmental crime of the 21st century. Jakarta Globe. http://jakartaglobe.beritasatu.com/opinion/erik-meijaard-indonesias-fire-crisis-biggest-environmental-crime-21st-century/ (Accessed 27 October 2015).

Meijaard E, Sheil D, Nasi R, Augeri D, Rosenbaum B, Iskandar D, Setyawati T, Lammertink M, Rachmatika I, Wong A, Soehartono T, Stanley S & O'Brien T (2005) Life After Logging: Reconciling Wildlife Conservation and Production Forestry in Indonesian Borneo. CIFOR (Center for International Forestry Research) and UNESCO, Jakarta, Indonesia, xxii + 345 pp.

Meijaard E, Buchori D, Hadiprakoso Y, Utami-Atmoko SS, Nurcahyo A, Tiju A, Prasetyo D, Nardiyono, Christie L, Ancrenaz M, Abadi F, Antoni ING, Armayadi D, Dinato A, Ella, Gumelar P, Indrawan TP, Kussaritano, Munajat C, Nurcahyo A, Priyono CWP, Purwanto Y, Puspitasari D, Putra MSW, Rahmat A, Ramadani H, Sammy J, Siswanto D, Syamsuri M, Andayani M, Wu H, Wells JA & Mengersen K (2011) Quantifying killing of orangutans and human–orangutan conflict in Kalimantan, Indonesia. PLoS One, 6(11): e27491.

Mohamed A, Ross J, Hearn AJ, Cheyne SM, Alfred R, Bernard H, Boonratana R, Samejima H, Heydon M, Augeri DM, Brodie J, Giordano AJ, Fredriksson G, Hall J, Loken B, Nakashima Y, Pilgrim JD, Rustam, Semiadi G, van Berkel T, Hon J, Lim NTL, Marshall AJ, Mathai J, Macdonald DW, Breitenmoser-Würsten C, Kramer-Schadt S & Wilting A (2016) Predicted distribution of leopard cat *Prionailurus bengalensis* (Mammalia: Carnivora: Felidae) on Borneo. Raffles Bulletin of Zoology, Supplement 33: 180–183.

Murphy A (2007) An Evaluation of Subsistence Hunting in the Community of Buayan-Kionop, Sabah. Final Report submitted to the Rufford Foundation, London, U.K., 21 pp.

Naidoo R, Malcolm T & Tomasek A (2008) Economic benefits of standing forests in highland areas of Borneo: quantification and policy impacts. Conservation Letters, 2: 36–45.

Obidzinski K, Meijaard E, Gaveau D, Orth M, Dermawan A, Gnych S, Andriani R & Husnayaen EM (in prep.) King coal: the rise of coal-mining industry and its implications for Indonesia's forests.

Petersen R, Gibbes S & Weisse M (2015) New GFW maps show vast logging, oil palm and plantation concessions in Sarawak. World Resources Institute http://www.wri.org/blog/2015/11/new-gfw-maps-show-vast-logging-oil-palm-and-plantation-concessions-sarawak (Accessed 20 November 2015).

Poole CM (2003) The first records of hairy-nosed otter *Lutra sumatrana* from Cambodia with notes on the national status of three other otter species. Natural History Bulletin of the Siam Society, 51: 273–280.

Puri RK (2001) Bulungan Ethnobiology Handbook. A Field Manual for Biological and Social Science Research on the Knowledge and Use of Plants and Animals among 18 Indigenous Groups in Northern East Kalimantan. Centre for International Forestry Research, Bogor, Indonesia, xxxv + 310 pp.

Rajaratnam R, Sunquist M, Rajaratnam L & Ambu L (2007) Diet and habitat selection of the leopard cat (*Prionailurus bengalensis borneoensis*) in an agricultural landscape in Sabah, Malaysian Borneo. Journal of Tropical Ecology, 23: 209–217.

Runting RK, Meijaard E, Abram NK, Wells, JA, Gaveau DLA, Ancrenaz M, Possingham HP, Wich SA, Ardiansyah F, Gumal MT, Ambu LN & Wilson KA (2015) Alternative futures for Borneo show the value of integrating economic and conservation targets across borders. Nature Communications, 6(6819): 1–10.

Rustam, Hearn AJ, Ross J, Alfred R, Samejima H, Heydon M, Cheyne SM, Brodie J, Giordano AJ, Bernard H, Boonratana R, Loken B, Mohamed A, Augeri DM, Eaton J, Hon J, Lim BL, Marshall AJ, Mathai J, Semiadi G, Macdonald DW, Breitenmoser-Würsten C, Kramer-Schadt S & Wilting A (2016) Predicted distribution of the Marbled Cat *Pardofelis marmorata*

(Mammalia: Carnivora: Felidae) on Borneo. Raffles Bulletin of Zoology, Supplement 33: 157–164.

Samejima H, Meijaard E, Duckworth JW, Yasuma S, Hearn AJ, Ross J, Mohamed A, Alfred R, Bernard H, Boonratana R, Pilgrim JD, Eaton J, Belant JL, Kramer-Schadt S & Wilting A (2016) Predicted distribution of the Sunda Stink-badger *Mydaus javanensis* (Mammalia: Carnivora: Mephitidae) on Borneo. Raffles Bulletin of Zoology, Supplement 33: 61–70.

Santika T, Meijaard E & Wilson KA (2015) Designing multifunctional landscapes for forest conservation. Environmental Research Letters, 10(114012): 1–9.

Sarawak Forest Department (2015) Facts & Figures. http://www. forestry.sarawak.gov.my/modules/web/pages.php?mod=webp age&sub=page&id=117&menu_id=0&sub_id=140 (Accessed 1 September 2015).

Schreiber A, Wirth R, Riffel M & Van Rompaey H (1989) Weasels, civets, mongooses, and their relatives. An action plan for the conservation of mustelids and viverrids. IUCN, Gland, Switzerland, 100 pp.

Shepherd CR, Belant JL, Breitenmoser-Würsten C, Duplaix N, Ambu LN & Wilting A (2011) Conservation challenges and opportunities for Borneo's carnivores. TRAFFIC Bulletin, 23: 89–91.

Shirley R & Kammen D (2015) Energy planning and development in Malaysian Borneo: assessing the benefits of distributed technologies versus large scale energy mega-projects. Energy Strategy Reviews, 8: 15–29.

Siegert F, Ruecker G, Hinrichs A & Hoffmann AA (2001) Increased damage from fires in logged forests during droughts caused by El Niño. Nature, 414: 437–440.

Smith J, Obidzinski K, Subarudi S & Suramenggala I (2003) Illegal logging, collusive corruption and fragmented governments in Kalimantan, Indonesia. International Forestry Review, 5: 293–302.

Streicher U & Ulibarri L (2014) Observations of small carnivores in Son Tra Nature Reserve, a small and isolated protected area in central Vietnam. Small Carnivore Conservation, 51: 18–22.

Struebig MJ, Wilting A, Gaveau DLA, Meijaard E, Smith RJ, the Borneo Mammal Distribution Consortium, Fischer M, Metcalfe K & Kramer-Schadt S (2015a) Targeted conservation to safeguard a biodiversity hotspot from climate and land-cover change. Current Biology, 25: 372–378.

Struebig MJ, Fischer M, Gaveau DLA, Meijaard E, Wich SA, Gonner C, Sykes R, Wilting A & Kramer-Schadt S (2015b) Anticipated climate and land-cover changes reveal refuge areas for Borneo's orang-utans. Global Change Biology, 21: 289–2904.

Tawie S (2015) CM pulls the brakes on Baram dam until he goes through detailed studies, group claims. The Malay Mail Online http://www.themalaymailonline.com/malaysia/article/ cm-pulls-the-brakes-on-baram-dam-until-he-goes-through-detailed-studies-gro (Accessed 15 November 2015).

The Star Online (2015) Bush meat widely sold in Sabah. http:// www.thestar.com.my/News/Nation/2015/11/23/Bush-meat-widely-sold-in-Sabah/ (Accessed 24 November 2015).

Uluk A, Sudana M & Wollenberg E (2001) Dayak community dependence on the forest surrounding Kayan Mentarang National Park. CIFOR, Bogor, Indonesia, 262 pp. [In Indonesian].

Venter O, Meijaard E, Possingham HP, Dennis R, Sheil D, Wich S, Hovani L & Wilson K (2009) Carbon payments as a safeguard for threatened tropical mammals. Conservation Letters, 2: 123–129.

Wearn OR, Rowcliffe JM, Carbone C, Bernard H & Ewers RM (2013) Assessing the status of wild felids in a highly-disturbed commercial forest reserve in Borneo and the implications for camera trap survey design. PLoS One, 8(11): e77598.

Wildlife Conservation Society and Sarawak Forest Department (1996) A Master Plan for Wildlife in Sarawak. Wildlife Conservation Society and Sarawak Forest Department, Kuching, Sarawak, Malaysia, 346 pp.

Willcox DHA, Tran QP, Hoang MD & Nguyen TTA (2014) The decline of non-*Panthera* cat species in Vietnam. Cat News, Special Issue 8: 53–61.

Wilting A, Mohamed A, Ambu LN, Lagan P, Mannan S, Hofer H & Sollmann R (2012) Sunda clouded leopard *Neofelis diardi* density in two used forests in Sabah, Malaysian Borneo. Oryx, 46: 423–426.

Wilting A, Duckworth JW, Hearn AJ and Ross J (2015) *Melogale everetti*. In: IUCN Red List of Threatened Species. www. iucnredlist.org/details/13110/0 (Accessed 20 November 2015).

Wilting A, Duckworth JW, Belant JL, Duplaix N & Breitenmoser-Würsten C (2016a) Introduction: distribution of and conservation priorities for Bornean small carnivores and cats. Raffles Bulletin of Zoology, Supplement 33: 1–8.

Wilting A, Hearn AJ, Eaton J, Belant JL & Kramer-Schadt S (201xb) Predicted distribution of the Bornean ferret badger *Melogale everetti* (Mammalia: Carnivora: Mustelidae) on Borneo. Raffles Bulletin of Zoology, Supplement 33: 55–60.

Wilting A, Cheyne SM, Mohamed A, Hearn AJ, Ross J, Samejima H, Boonratana R, Marshall AJ, Brodie JF, Giordano AJ, Eaton JA, Hall J, Pilgrim JD, Heydon M, Semiadi G, Meijaard E, Macdonald DW, Breitenmoser-Würsten C & Kramer-Schadt S (2016c) Predicted distribution of the flat-headed cat *Prionailurus planiceps* (Mammalia: Carnivora: Felidae) on Borneo. Raffles Bulletin of Zoology, Supplement 33: 173–179.

WWF (2015) WWF in Borneo and how it supports the Heart of Borneo Initiative. WWF Indonesia. http://wwf.panda.org/what_ we_do/where_we_work/borneo_forests/resources/?240151/ WWF-in-Borneo-and-How-it-supports-The-Heart-of-Borneo-Initiative (Accessed 1 September 2015).

Yue S, Brodie JF, Zipkin EF & Bernard H (2015) Oil palm plantations fail to support mammal diversity. Ecological Applications, 25(8): 2285–2292.

Zhang H, Miller MP, Yang F, Chan HK, Gaubert P, Ades G & Fischer GA (2015) Molecular tracing of confiscated pangolin scales for conservation and illegal trade monitoring in Southeast Asia. Global Ecology and Conservation, 4: 414–422.

217