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Introduction: distribution of and conservation priorities for Bornean small carnivores and cats

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In the current 'sixth mass extinction event in the history of life', biological diversity (biodiversity, i.e., genetic diversity, species diversity and ecosystem diversity) is decreasing at 100–1000 times the pre-human rates (Chapin et al., 2000; Sachs et al., 2009). Because of the exceptional species richness of tropical rainforests, their destruction causes the highest biodiversity losses (Brooks et al., 2002).

The islands of South-east Asia are global biodiversity hotspots (Myers et al., 2000), hosting about 13% of all known mammal species on only about 1% of the world's land area (Meijaard, 2009). The mammals of South-east Asia are of high global conservation priority (Schipper et al., 2008; Sodhi et al., 2010). Within South-east Asia, Borneo has been identified as an evolutionary hotspot hosting the highest levels of mammalian species richness (de Bruyn et al., 2014). But this biodiversity hotspot is under sustained pressure from anthropogenic habitat conversion: between 1973 and 2010 over 30% of Borneo's forests were cleared (Gaveau et al., 2014). Of the remaining forest, a large proportion is earmarked for the conversion to non-forest use (Gaveau et al., 2013). In addition to habitat conversion, there are major pressures from habitat degradation and fragmentation; furthermore, hunting is a serious threat to many mammals on Borneo (e.g., Bennett et al., 1995, 2000; Brodie et al., 2015).

Borneo harbours altogether 25 species of carnivores (Table 1), including more endemic carnivores than any other island except Madagascar (Shepherd et al., 2011); some of these are remarkably distinct from all other global forms, such as Hose's civet *Diplogale hosei* (Thomas). Presently, about half of the carnivore species whose geographic ranges include Borneo have been classified by The IUCN Red List of Threatened Species as globally threatened (IUCN, 2015). Alarmingly, between the IUCN Red List assessments of 2002 and 2008, three species were moved from Near Threatened or Least Concern to Vulnerable, and two from Data Deficient or Vulnerable to Endangered (Shepherd et al., 2011), whilst two Bornean carnivores were categorised as Data Deficient in 2008. In response to these threats and paucity of knowledge, three IUCN SSC specialist groups (the Cat Specialist Group, the Otter Specialist Group and the Small Carnivore Specialist Group), in collaboration with the Sabah Wildlife Department and the Leibniz Institute for Zoo and Wildlife Research (IZW) organised the '1st Borneo Carnivore Symposium (BCS): Road Towards Conservation Action Plans' (18–24 June 2011 in Kota Kinabalu, Sabah, Malaysia) in order to determine the most urgent needs in developing strategies for the conservation of Bornean carnivores.

A key focus of the BCS was to enhance the dialogue between scientists, conservationists and governmental authorities of these countries. The BCS presented the unique opportunity for closer connections between scientists and practitioners and was the first time that researchers and governmental authorities in Borneo sat down to (i) discuss the future of carnivores, a group of species often side-lined in Borneo in favour of more charismatic species such as Bornean orang-utan *Pongo pygmaeus* (Linnaeus) and Asian elephant *Elephas maximus* Linnaeus; (ii) identify key conservation areas within their respective regions; and (iii) discuss the main threats and necessary actions to mitigate these threats, in addition to possibilities of transboundary cooperation. The BCS was attended by about 200 people from almost 20 countries, with strong representation from the range states of Brunei Darussalam, Malaysia and Indonesia, the three countries comprising Borneo. The BCS had two parts: Part I entitled 'Science for conservation of Bornean carnivores' and Part II 'Developing conservation strategies for Bornean carnivores'.

A key objective of the BCS was to build a knowledge base of Bornean carnivores. To this end, staff at the IZW collated occurrence records of all Bornean carnivores except sun bear *Helarctos malayanus* (Raffles) in advance of the BCS, and established the Borneo Carnivore Database (see Kramer-Schadt et al., 2016). Many national and international scientists, conservationists and/or naturalists responded to

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Table 1 List of carnivore species included in the Borneo Carnivore Symposium. Sequence follows Mammals of Borneo (Payne et al., 2007), except *Mydaus javanensis* and *Prionodon linsang*, placed in their respective subsequently recognised families Mephitidae and Prionodontidae.

Scientific name	Species authority	English name	Malay name	Indonesian name	IUCN Red List status[1]	World Range[2]
Caniformia - Mustelidae (Small carnivores[3])						
Martes flavigula	(Boddaert, 1785)	yellow-throated marten	Mengkira	Musang Leher-Kuning	Least Concern	W
Mustela nudipes	Desmarest, 1822	Malay weasel	Pulasan Tanah	Musang Kepala-Putih	Least Concern	GS
Melogale everetti	(Thomas, 1895)	Bornean ferret badger	Pulsan Lamri	Biul Slentek	Data Deficient	B
Lutra sumatrana[4]	(Gray, 1865)	hairy-nosed otter	Memerang Kumis	Berang-Berang Sumatera	Endangered	SEA
Lutra lutra[4]	(Linnaeus, 1758)	Eurasian otter	Memerang 'Eurasian'	Berang-Berang Pantai	Near Threatened	W
Lutrogale perspicillata[4]	(Geoffroy Saint-Hilaire, 1826)	smooth-coated otter	Memerang Licin	Berang-Berang Wregul	Vulnerable	W
Aonyx cinereus[4]	(Illiger, 1815)	Asian small-clawed otter	Memerang Kecil	Sero Amblang	Vulnerable	W
Caniformia – Mephitidae (Small carnivores[3])						
Mydaus javanensis	(Leschenault, in Desmarest, 1818)	Sunda stink-badger	Teledu	Teledu Sigung	Least Concern	GS
Feliformia – Prionodintidae (Small carnivores[3])						
Prionodon linsang	(Hardwicke, 1821)	banded linsang	Linsang	Linsang Linsang	Least Concern	GS
Feliformia – Viverridae (Small carnivores[3])						
Viverra tangalunga	Gray, 1832	Malay civet	Musang Tenggalung	Tenggalung Malaya	Least Concern	GS
Paradoxurus hermaphroditus	(Pallas in von Schreber, 1777)	common palm civet	Musang Pulut	Musang Luwak	Least Concern	W
Paguma larvata	(Smith, 1827)	masked palm civet	Musang Lamri	Musang Galing	Least Concern	W
Arctictis binturong	(Raffles, 1821)	binturong	Binturong	Binturung	Vulnerable	SEA
Arctogalidia trivirgata	(Gray, 1832)	small-toothed palm civet	Musang Akar	Musang Akar	Least Concern	SEA
Hemigalus derbyanus	(Gray, 1837)	banded civet	Musang Belang	Musang Belang	Vulnerable	GS
Diplogale hosei	(Thomas, 1892)	Hose's civet	Musang Hitam Pudar	Musang Gunung	Vulnerable	B
Cynogale bennettii	Gray, 1837	otter civet	Musang Memerang	Musang Air	Endangered	GS

Scientific name	Species authority	English name	Malay name	Indonesian name	IUCN Red List status[1]	World Range[2]
Feliformia – Herpestidae (Small carnivores[3])						
Herpestes brachyurus	Gray, 1837	short-tailed mongoose	Bambun ekor pendek	Garangan Ekor-Pendek	Least Concern	GS
Herpestes semitorquatus	Gray, 1846	collared mongoose	Bambun Ekor Pendek	Garangan Ekor-Panjang	Data Deficient	GS
Feliformia – Felidae (Cats)						
Neofelis diardi	(Cuvier, 1823)	Sunda clouded leopard	Harimau Dahan	Macan Dahan	Vulnerable	GS
Pardofelis marmorata	(Martin, 1837)	marbled cat	Kucing Dahan	Kucing Batu	Vulnerable	SEA
Catopuma badia	(Gray, 1874)	bay cat	Kucing Merah	Kucing Merah	Endangered	B
Prionailurus planiceps	(Vigors & Horsfield, 1827)	flat-headed cat	Kucing Hutan	Kucing Tandang	Endangered	GS
Prionailurus bengalensis	(Kerr, 1792)	leopard cat	Kucing Batu	Kucing Kuwuk	Least Concern	W

[1]As this supplementary issue was being finalised, the Red List categories of all the species were reviewed, making free use of BCS information. At the time of going to press, the following changes had occurred *Melogale everetti* → Endangered; *Hemigalus derbyanus* → Near Threatened; *Herpestes semitorquatus* → Near Threatened; *Pardofelis marmorata* → Near Threatened; others are anticipated in early-mid 2016; [2] B = Borneo; GS = Greater Sunda subregion including Borneo, Java, Sumatra, the Thai–Malay peninsula and associated islands; SEA = Southeast Asia including marginal China, NE India & Nepal); W = wider range; [3] All species are small carnivorans, but throughout this issue the term 'small carnivore' is used for those species within the remit of the IUCN SCC Small Carnivore Specialist Group; [4] because of paucity of occurrence records and other Borneo-specific information, otters were excluded from this supplement.

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the query and contributed their records and knowledge from Borneo. This collaborative work of the Borneo Carnivore Consortium (see Table 2) sets the foundation for the successful BCS and for this Supplement of the Raffles Bulletin of Zoology.

These collated records were used to model the potential current distribution of all Bornean small carnivores (this term used here in correspondence with IUCN SSC specialist group arrangement, i.e., in Bornean terms to signify all carnivores except otters, cats and Sun Bear), otters and cats. The spatial predictions were presented by local and international scientists to the other participants of the BCS. For each species, scientists, conservationists and other stakeholders discussed afterwards the model's outcomes and suggested conservation priorities. In regional working groups these conservation priorities were specified further and participants of the BCS proposed key areas for protection or sustainable management to safeguard the most threatened Bornean carnivores. These discussions recognised the need to publish the BCS findings for each species, and the Raffles Bulletin of Zoology provided us the opportunity to do so in this Supplement.

After the BCS the species distribution models were refined using the input and recommendations of the participants. A particular requirement was a more rigorous approach to account for the uneven search effort across the island, because until today most research, surveys, and leisure natural history observations have been conducted in the Malaysian state of Sabah, whilst very limited work has been conducted in the provinces of South Kalimantan and West Kalimantan, Indonesia. Although there is no possibility to avoid erroneous predictions because of uneven search effort, the risks were reduced by the approaches developed in Kramer-Schadt et al. (2013) and described also in Kramer-Schadt et al. (2016). Most importantly, the methodological outline and the species papers all highlight the approach's limitations.

This thorough revision revealed that any modelling approach for the Bornean otters would be unlikely to produce scientifically sound results, because of the paucity of then-available occurrence records. All four Bornean otters are likely to be highly threatened on the island. Indeed, until recent photographs were taken taken from Danum Valley (N.D. pers. communication) it was unknown if the Eurasian otter *Lutra lutra* (Linnaeus) persisted on Borneo at all. Although the other three otter species, the hairy-nosed otter *Lutra sumatrana* (Gray), the Asian small-clawed otter *Aonyx cinereus* (Illiger) and the smooth-coated otter *Lutrogale perspicillata* (Geoffroy Saint-Hilaire) are somewhat more commonly recorded, the number of confirmed records with precise spatial information even for each of these remained too low for credible modelling. Although it is unfortunate that the otters could not be covered in comparable fashion in this Supplement, that so little is known about them highlights the urgent need for further information to be gathered and, almost certainly, for conservation actions on Borneo. In South-east Asia and East Asia, otters are heavily hunted and traded, particularly for their skins; and their primary habitat, the wetlands, most of which are in the lowlands, are the most threatened habitats in South-east Asia (Posa et al., 2011; Miettinen et al., 2011). In the overall Bornean carnivore community paper, Mathai et al. (2016) used the otter civet *Cynogale bennettii* Gray and the flat-headed cat *Prionailurus planiceps* (Vigors & Horsfield), two other Bornean carnivores highly dependent upon surface water sources and which are almost confined to wetlands and/or lowland forest, to highlight the conservation need to protect these threatened areas. It is likely that also all four Bornean otter species would benefit from such conservation activities.

This supplement starts with an overview from Earl of Cranbrook (2016) about the biogeographical influences on and the zooarchaeology of Bornean carnivores. He summarised the fossil records of carnivores and showed how these remains can provide intriguing biogeographical, environmental and cultural information.

The methodological approach from data collection to the predictions of the habitat suitability index model is presented by Kramer-Schadt et al. (2016). This paper serves not only as a 'Material and Methods' section for all subsequent papers but by highlighting the approach's limitations it is essential context for the presented findings. This paper is followed by 15 small carnivore and five cat papers, each presenting the records traced, the predicted distribution and the proposed conservation needs for the species in question.

The supplementary issue concludes with an overarching paper by Mathai et al. (2016), which puts the findings of each species into a broader Borneo carnivore conservation context. This paper highlights the most urgent conservation and research needs for the Bornean carnivore community as a whole.

We are thrilled that in the five years since the BCS many more research activities on Borneo have generated new information, of which not all could be incorporated in this Supplement. Nevertheless we trust that this issue will serve as a foundation for more concentrated research and conservation activities, both at the species-level, but also at the biodiversity level, as carnivores – being on top of the food chain – are known to play important roles in the ecosystem functioning. Thus, many findings presented here, specifically in the concluding paper of Mathai et al. (2016), are representative of broader conservation issues on Borneo. We hope that the joint effort of the Borneo Carnivore Consortium will serve as a catalyst for future collaborative initiatives.

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