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Predicted distribution of the binturong *Arctictis binturong* (Mammalia: Carnivora: Viverridae) on Borneo

Gono Semiadi[1]*†, Joanna Ross[2]*†, Andrew J. Hearn, Matt Heydon, Hiromitsu Samejima, John Mathai, Dave Augeri, Gabriella Fredriksson, Norman T.-L. Lim, Rustam, Azlan Mohamed, Ramesh Boonratana, Jedediah F. Brodie, Anthony Giordano, Yoshihiro Nakashima, Tim van Berkel, Jason Hon, Brent Loken, Andrew J. Marshall, David W. Macdonald, Jerrold L. Belant, Stephanie Kramer-Schadt and Andreas Wilting

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

Abstract. The binturong *Arctictis binturong* is a medium-sized carnivore in the civet family Viverridae with a wide geographic distribution in South-east Asia and adjacent parts of South Asia and China. Habitat loss and hunting have led to its classification as Vulnerable by The IUCN Red List of Threatened Species. The binturong is thought to be forest dependent, although it has been recorded in logged forest and its exact habitat requirements remain unclear. We analysed 47 (Balanced Model) or 83 (Spatial Filtering Model) location records, respectively, to predict habitat suitability across Borneo. The results of the model predict a large area of Borneo to be suitable habitat although the extreme lowlands and much of southern Borneo (South Kalimantan) are predicted to be less suitable or non-sampled, respectively. There is high overlap between protected areas and areas of predicted high suitability. The interior of Borneo, in particular North Kalimantan, is predicted to be highly suitable. A greater survey effort for the binturong in the hitherto less studied Brunei Darussalam and South Kalimantan is warranted.

Key words. Binturong, *Arctictis binturong*, forest management, habitat suitability, MaxEnt modelling

Abstrak (Bahasa Indonesia). Binturong *Arctictis binturong* merupakan karnivora berukuran sedang dari keluarga musang dengan persebaran geografisnya yang luas, meliputi Asia Tenggara dan sebagian Asia Selatan dan China. Hilangnya habitat serta perburuan menjadikan satwa ini dikategorikan Rentan dalam daftar IUCN Red List of Threatened Species. Binturong diperkirakan sebagai satwa yang tergantung pada lingkungan hutan, walau pernah tercatat berada pada wilayah hutan hasil tebangan, namun kebutuhan habitat sebenarnya belum jelas. Kami menganalisa 47 (Model Penyeimbang) atau 83 (Model Spasial Tersaring) catatan keberadaan binturong guna memperkirakan kesesuaian habitat di wilayah Borneo. Hasil dari pemodelan menunjukkan sebagian besar wilayah Borneo diperkirakan merupakan habitat yang sesuai, walau wilayah dataran rendah dan sebagain besar Borneo bagian selatan (Kalimantan Selatan) tampaknya kurang sesuai bahkan belum ada data. Banyak kawasan yang tumpang tindih diantara wilayah perlindungan dengan wilayah yang diperkirakan memiliki kesesuaian tinggi. Bagian pedalaman Borneo, khususnya Kalimantan Utara, diperkirakan merupakan wilayah yang sangat sesuai. Suatu survey yang lebih mendalam pada wilayah yang hingga kini kurang diperhatikan, Brunei Darussalam dan Kalimantan Selatan, diperlukan guna mengkaji status binturong di wilayah tersebut.

Abstrak (Bahasa Malaysia). Binturong *Artictis binturong* adalah karnivora dari keluarga musang yang bersaiz sederhana. Ia mempunyai taburan geografi yang luas meliputi Asia Selatan dan Asia Tenggara. Kehilangan habitat dan pemburuan telah menyebabkan ia disenarai sebagai Terancam di dalam Senarai Merah Spesis Terancam IUCN (IUCN Red List of Threatened Species). Binturong dianggap sebagai spesis yang bergantung kepada hutan; walaupun ia pernah direkodkan di kawasan yang sudah dibalak tetapi keperluan habitatnya yang sebenar masih lagi kurang diketahui. Kami menganalisis 47 rekod lokasi (model seimbang) dan 83 rekod lokasi (model yang ditapis secara spasial) untuk meramal kesesuaian habitat binturong di seluruh Borneo. Keputusan pemodelan meramalkan sebahagian besar Borneo sebagai habitat yang sesuai, namun kawasan yang sangat rendah dan sebahagian selatan Borneo (Kalimantan Selatan) diramal sebagai kurang sesuai. Terdapat pertindihan yang tinggi antara kawasan perlindungan dan kawasan yang diramal mempunyai kesesuaian yang tinggi. Bahagian pedalaman Borneo diramal sangat sesuai, terutamanya di Kalimantan Utara. Penyelidikan yang lebih lanjut di kawasan yang kurang dibuat kajian seperti di Brunei Darussalam dan Kalimantan Selatan diperlukan untuk menilai status binturong di kawasan tersebut.

INTRODUCTION

The binturong *Arctictis binturong* (Raffles), is a medium-sized carnivore of the civet family Viverridae. It is relatively easily recognised (Fig. 1A): the longish coat is solid black/grizzled in colour, the ears have unmistakable long tufts of hair and the tail is long, thick and prehensile. It is widely distributed in South-east Asia and adjacent parts of South Asia and China (Widmann et al., 2008; Jennings & Veron, 2009). The diet of the binturong consists of fruit, especially figs and also small animals (Payne et al., 1998); Marshall et al. (2009) found the species to be a fairly unspecialised frugivore compared with most other mammals and birds at Gunung Palung National Park, West Kalimantan. The Binturong is active during both night and day (Payne et al., 1998), although it is currently unclear if activity patterns vary regionally. Ross et al. (in press.), from camera-trap data in Sabah, Malaysian Borneo, found ground-level activity to be mainly diurnal, peaking between 1400 and 1600 hours.

The binturong has never been the focus of any intensive field study, but it is believed to be largely dependent upon forest. Habitat loss and degradation across its range, coupled with hunting, especially in its mainland range, have resulted in its listing as Vulnerable on The IUCN Red List of Threatened Species (Widmann et al., 2008). Although the binturong has been recorded at elevations up to 1500 m above sea level (a.s.l.) on Borneo (Payne et al., 1998) it is not a montane specialist and therefore is likely to have suffered from the extensive alteration of lowland habitat (Widmann et al., 2008). This species was considered by Hose (1893) to be common in Sarawak and usually found in dense forest. It was also reported as quite common in the Kelabit Highlands by Davis (1958). In more recent years, it has been recorded from logged forest on Borneo (e.g., Heydon & Bulloh, 1996; Mohd-Azlan & Lading, 2006; Mathai et al., 2010; Wilting et al., 2010; Brodie & Giordano, 2011; Samejima et al., 2012; Ross et al., in press; B. Loken & Kasyanto, unpubl. data), with Meijaard et al. (2008) classifying it as tolerant of moderate intensity logging. The binturong has not been detected in oil palm plantations (Ross et al., in press; Yue et al., 2015), acacia plantations (Belden et al., 2007), or regenerating burnt forest areas (Rustam et al., 2012). Although it is fairly arboreal it does descend to the ground, perhaps to move between trees (Than Zaw et al., 2008) or to visit salt licks (Matsubayashi et al., 2007) when it may be exposed to ground-based threats such as snares. In some parts of Borneo it is killed for food (Uluk et al., 2001; Murphy, 2007).

Fig. 1. A, binturong *Arctictis binturong* camera-trapped in Deramakot Forest Reserve, Sabah, Malaysia on 11 November 2014; B, binturong camera-trapped in peat-swamp forest at Sabangau National Park, Central Kalimantan, Indonesia, well south of the specimen-validated Bornean range on 11 July 2011 (Photograph by: A. Mohamed/IZW, SFD [A]; Susan M Cheyne/OuTrop [B]).

The binturong is included in Schedule 2 of Sabah's Wildlife Conservation Enactment 1997 under which hunting and collection is allowed with appropriate license issued by the Sabah Wildlife Department. Similarly in Sarawak, it is protected under the Wildlife Protection Ordinance 1998. In Indonesia it is protected under Indonesia's Government Regulation No. 7/1999. In Brunei however, it is not legally protected.

RESULTS

Species occurrence records. Of 172 location records for the Binturong collated, 54 were discounted from modelling because of spatial imprecision (Table 1). A total of 79 records were obtained during 2001–2011 (Table 1, Fig. 2). Records came from across Borneo except for South Kalimantan and Brunei. A disproportionately high number of records were from Sabah, and a large number of these records had high spatial precision; in contrast, no records of high precision were available from West Kalimantan. To predict habitat suitability for the entire island (Balanced Model) we used 47 records. For predicting the habitat suitability in Sabah (Spatially Filtered Model), we used 83 records (Fig. 3).

[1]Research Centre for Biology, Indonesian Institute for Sciences (LIPI), Cibinong-Bogor 16911, Indonesia; Email: semiadi@yahoo.com (*corresponding author)

[2]Wildlife Conservation Research Unit (WildCRU), Department of Zoology, University of Oxford, Recanati- Kaplan Centre, Tubney House Abingdon Road, Tubney, Oxfordshire, OX13 5QL. U.K.; Email: joanna.ross@zoo.ox.ac.uk (*corresponding author)

†contributed equally in writing manuscript

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Table 1. Summary of the occurrence records for the binturong *Arctictis binturong* on Borneo.

Spatial Precision	Total No. of Records	No. of Records in M_1	No. of Records in M_2	No. of Recent Records 2001–2011
Category 1 below 500 m	51	19	43	49
Category 2 500 m – 2 km	17	12	14	11
Category 3 2–5 km	50	16	26	10
Category 4 above 5 km	31	–	–	7
Category 5 (no coordinates*)	23	–	–	2
Total	**172**	**47**	**83**	**79**

M_1 = Balanced Model; M_2 = Spatial Filtering Model (2 km); *only coarse location description was available.

Table 2. Land-cover reclassification for the binturong *Arctictis binturong* based on the questionnaire results of 10 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.70	3–4
Upland forest	3.13	1–4
Lower montane forest	3.13	1–4
Upper montane forest	2.13	0–4
Forest mosaics/lowland forest	2.52	*
Forest mosaics/upland forest	2.31	#
Swamp forest	2.13	0–4
Mangrove	0.57	0–2
Old plantations	1.71	0–3
Young plantations and crops	0.43	0–2
Burnt forest area	0.75	0–3
Mixed crops	0.70	0–3
Bare area	0.00	0–0
Water and fishponds	0.13	0–1
Water	0.00	0–0

*/#Calculated based on the mean of the reclassification of old plantation and *lowland forest or #upland forest, respectively.
Habitat suitability rank ranges from 0 (unsuitable) to 4 (most suitable); further detail, and on land-cover classes, in Kramer-Schadt et al. (2016).

Habitat associations. There was a general consensus among the 10 respondents that lowland, upland and lower montane forest were all suitable binturong habitat; lowland forest scored the highest. In contrast, plantations, burnt forest, bare areas and water were considered to be poor or unsuitable. There was, however, little consistency among respondents for swamp forest and upper montane forest, with values ranging from 0 (non-habitat) to 4 (good habitat); and agreement for several other habitat categories was also low (Table 2).

Habitat suitability index (HSI) model. The final habitat suitability model (see Kramer-Schadt et al., 2016) predicted a relatively large area of Borneo to be suitable for the binturong (Fig. 3). Most of this predicted area is in the north and towards the interior of Borneo. There is considerable overlap between areas of predicted high suitability and protected areas; however, the coastal areas, in their deforested parts, and much of southern Borneo is predicted to be unsuitable. However, the mapped predictions of the habitat suitability index model in Fig. 3 need to be interpreted with caution (see Kramer-Schadt et al. (2016) for more details). Of note, some areas, particular in South and West Kalimantan, had little information, reflecting the lower survey efforts in these areas. Although search-effort bias has been minimised during the modelling, these areas might still be underrepresented in the distribution map especially if they are climatically distinct from the rest of Borneo. This is particularly likely for South Kalimantan which has a more pronounced dry season (see Kramer-Schadt et al., 2016: Fig. 3A). Thus, unless there are records sufficiently spatially precise to have been

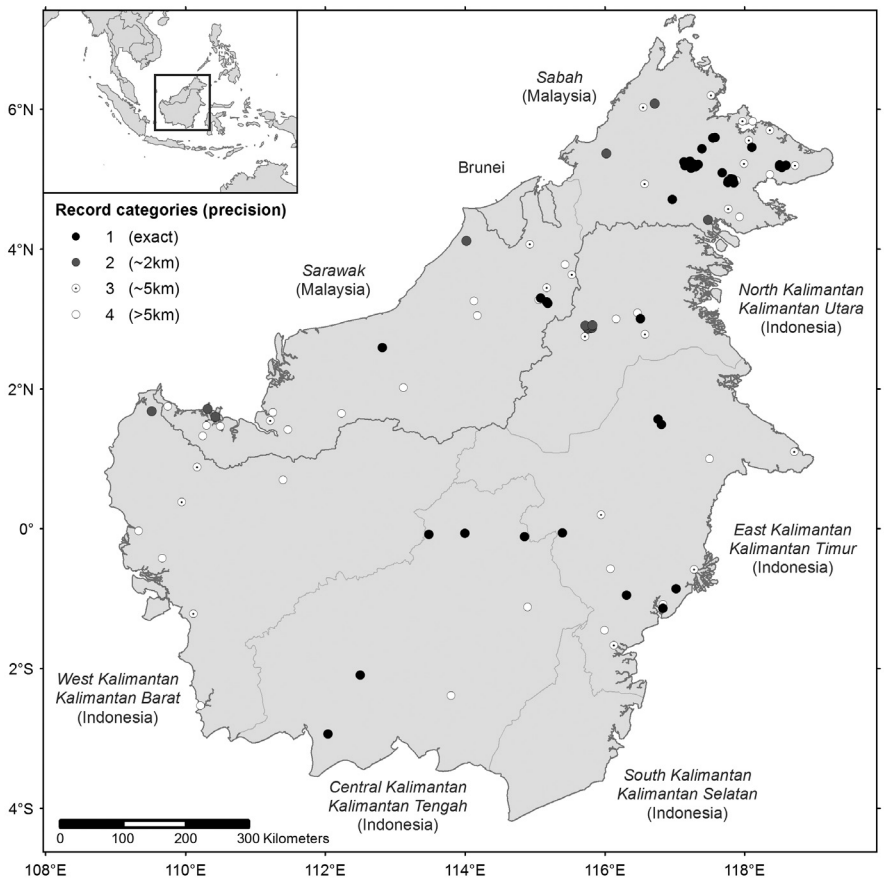

Fig. 2. Location of binturong *Arctictis binturong* occurrence records in Borneo, showing categories of spatial precision as well as country and state boundaries.

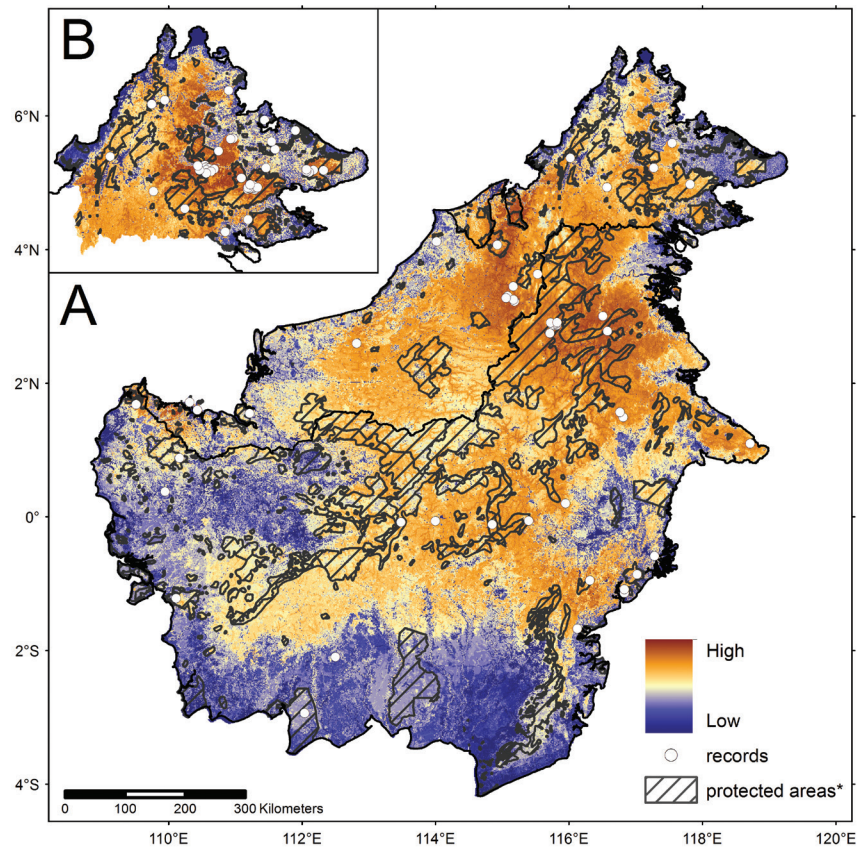

Fig. 3. Predictive Habitat Suitability Index (HSI) models for the binturong *Arctictis binturong* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al. (2016).

used in the model, the prediction cannot accurately reflect the potential for occurrence in that region. In general, only further surveys could determine if the lower predictions are because of the minimal survey efforts or reflect a genuine lower suitability of these areas for the species, perhaps because of different climatic conditions or because large areas have been transformed to unsuitable land-cover (see Kramer-Schadt et al. 2016: Fig. 3B).

DISCUSSION

Habitat suitability. Although the binturong has a wide geographic range, its precise habitat requirements and responses to habitat modification remain obscure. This exercise highlighted areas of Borneo with relatively little research attention such as Brunei and South Kalimantan. The wide range of values in the scoring of suitability for each habitat demonstrated the general lack of information concerning the habitat preferences of the binturong. This in turn will have caused some imprecision in the final model, which should therefore be interpreted with caution. Nonetheless, based on this predictive model, we have been able to suggest the following areas for the long-term conservation of the binturong in Borneo.

Sabah, Malaysia. Many protected areas in Sabah are predicted to be suitable for the binturong, for example the central forest block which consists of a network of totally protected areas and production forests. There are records from both protected areas (e.g., Brodie & Giordano, 2011; Ross et al., in press) and logging concessions (e.g., Heydon & Bulloh, 1996; Wilting et al., 2010; Samejima et al., 2012; Ross et al., in press).

Sarawak, Malaysia. As with Sabah, a high proportion of Sarawak is predicted to be good habitat for the binturong, consistent with the distribution of lowland and hill dipterocarp forests, and the higher elevation in the interior, including both protected and production forests. However, most of the records for the state are from outside the totally protected areas. For instance, there is a cluster of records from the area south of Pulong Tau National Park within a production forest where there are zones assigned for conservation by the logging concessionaire but are not legally protected by the government (Mathai et al., 2010). It is not clear whether this reflects survey bias/search-effort bias or whether there is poor overlap between binturong distribution and protected areas in Sarawak. There are also some records in areas predicted by the model to be of low suitability such as the area south of Lambir Hills National Park and the coastal areas in the south of the state. Further surveys and long term monitoring in these areas are needed to determine if they truly support binturong populations.

Brunei Darussalam. The majority of Brunei is predicted to be suitable habitat for the binturong, with Ulu Temburong National Park and Labi Hills Forest Reserve potential priority sites. The species has been confirmed in Gunung Mulu National Park in Sarawak, which together with Labi Hills forms a transborder protected area. Greater survey effort in the country would help elucidate its true distribution there.

East Kalimantan, Indonesia. The majority of East Kalimantan is predicted to be suitable habitat, including all protected areas except Muara Kaman Sedulang Nature Reserve. Unlike most of coastal Borneo, the Mangkalihat peninsula is predicted to be suitable and there are records from this area. Other coastal areas are predicted to be of low suitability although there are records from around Bukit Soeharto Nature Recreation Park.

South Kalimantan, Indonesia. Our model predicts that South Kalimantan is of very low suitability, reflecting the lack of records for the province. South Kalimantan has a more pronounced dry season than the rest of Borneo, which might make it unsuitable for some species. The binturong has a wide native distribution across South-east Asia including monsoonal areas, making a true absence from South Kalimantan less likely. South Kalimantan is under-surveyed compared with the rest of Borneo and wildlife surveys here would provide much-needed information regarding the mammal communities and their habitat associations in the province.

North Kalimantan, Indonesia. Most of the province is predicted to be suitable and although there are records from this area, they fall outside totally protected zones. The areas of highest suitability are predicted to be in the north: there is a cluster of records from the eastern edge of Kayan Mentarang National Park. Together with Pulong Tau NP and surrounding production forests in Sarawak, Kayan Mentarang NP forms a large transborder area potentially important for the binturong conservation.

Central Kalimantan, Indonesia. A large portion of Central Kalimantan is covered by peat swamp forest and is predicted to be unsuitable. Over 6000 camera-trap-nights in Sabangau National Park had not, by 2010, photographed the species, although it was sighted there directly (Cheyne et al., 2010) and has subsequently been camera-trapped there (Fig. 1B). This could reflect a chance that a low binturong population density, or perhaps that ground-level camera-traps are unlikely to record the species particularly in peat swamp forest. There is also a record from Tanjung Puting National Park, another area predicted to be of low suitability. Further surveys would clarify the presence and distribution of the binturong in peat and fresh water swamp forests.

West Kalimantan, Indonesia. None of the few binturong records from West Kalimantan were spatially precise. That our model predicted most of the province to be of low suitability for the species, including the protected areas, could be an artefact of low survey effort, rather than a valid reflection of habitat suitability.

General conclusions. The binturong appears to be distributed across most of Borneo. Medway's (1977) detailed collation of Bornean mammal records traced none of the binturong

with a precise location from south of the Sungai [=River] Ketungau in the upper Sungai Kapuas, West Kalimantan; Dingai in the upper Sungai Mahakam; or Kutai district in East Kalimantan. But he considered the species unlikely to be restricted to northern Borneo, and this suspicion can now be shown to be well-founded: Fig. 2 shows Binturong records almost to the south coast of Borneo, and S Cheyne (in litt., 2015) provided clear camera-trap images from Sabangau National Park (11 July 2011; too late for inclusion in the model) allowing independent verification of occurrence south to at least at 2°20'S (Fig. 1B).

In Borneo, the binturong does not seem to be restricted to any particular habitat although the extreme highlands and coastal areas were predicted to be generally less suitable. In the case of the highlands this might reflect low survey effort. In the case of the lowland areas this might be because of widespread clearance of natural forest. Although the binturong will use logged forests, the levels of change to forest structure and of the often associated hunting which it can withstand are unknown. Maintaining or re-establishing connectivity among forested areas and protected areas via the legal protection of habitat corridors is likely to be an important conservation priority for the species.

Like most species on Borneo, the binturong would benefit from targeted research to clarify its distribution and habitat requirements and to test this modelling exercise's predictions. Investigating the effects of hunting is a priority. For a species that is widely distributed and that occurs in various habitats, hunting might pose a greater risk than habitat loss; indeed in Vietnam and Lao PDR it has apparently been hunted out from, or to undetectably low densities in, various large tracts of little-degraded forest (Chutipong et al., 2014; RJ Timmins, DHA Willcox and JW Duckworth in litt. 2015). Because of its arboreal habits, it may be largely overlooked by methods designed for other species such as standard ground-level camera-trapping. Placing camera-traps at places where binturongs might have to descend to the ground, such as under canopy gaps, might increase detection probability, as might monitoring fruiting fig trees (Chutipong et al., 2014).

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