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Predicted distribution of the Bornean ferret badger *Melogale everetti* (Mammalia: Carnivora: Mustelidae) on Borneo

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

Abstract. The Bornean ferret badger *Melogale everetti* is one of the least known Bornean carnivores, and is currently classified as Data Deficient on The IUCN Red List of Threatened Species. Endemic to Borneo, it is associated with upland and highland forests in and around Kinabalu Park and Crocker Range Park. Of 52 Bornean ferret badger occurrence records, 14 were used to estimate potential habitat suitability. This species is likely to be confined to a very small range in western Sabah, potentially the smallest distribution range of any carnivore species in South-east Asia. All occurrence records were above 500 m elevation, which suggests that this species is restricted to upland and highland forests. Areas of particular importance predicted for survival of this species are Kinabalu Park, Crocker Range Park, and unprotected areas and commercial forest reserves east of Crocker Range Park. Because of the low number of recent records, the main threats to the Bornean ferret badger are unknown, but the transformation of forested areas to monoculture plantations and perhaps incidental hunting are likely to have negative effects on this species. As an upland and high-elevation specialist, climate change might also become an important future threat. Of particular importance for long-term survival of the Bornean ferret badger is an improved understanding of its current status, ecology and the threats it actually faces (if any).

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

Abstrak (Bahasa Indonesia). Biul Slentek *Melogale everetti* adalah salah satu jenis karnivora yang paling tidak dikenal, dan saat ini status konservasinya diklasifikasikan ke dalam jenis yang Datanya Kurang (DD) menurut Daftar Jenis Terancam Punah IUCN. Jenis ini merupakan jenis endemik Borneo dan hanya ditemukan di daerah dataran tinggi dan hutan di sekitar Taman Nasional Kinabalu dan Taman Banjaran Crocker di Sabah. Kami mengumpulkan 52 catatan kehadiran Biul Slentek, yang 14 catatan di antaranya digunakan untuk mengestimasi kesesuaian habitat. Jenis ini kehadirannya terbatas pada rentang wilayah yang sangat kecil di daerah barat Sabah, sehingga Biul Slentek memiliki daerah sebaran yang paling kecil dari seluruh karnivora di Asia Tenggara. Semua catatan kehadiran jenis ini tercatat pada elevasi melebihi 500 m di atas permukaan laut, yang menunjukkan jenis ini terbatas pada hutan dataran tinggi dan pegunungan. Kawasan penting yang diprediksi untuk jenis ini dapat bertahan hidup adalah Taman Nasional Kinabalu, Taman Banjaran Crocker dan kawasan yang tidak dilindungi dan kawasan pencadangan hutan produksi di sebelah timur Taman Banjaran Crocker. Karena sangat sedikitnya catatan kehadiran jenis ini sehingga ancaman utamanya di Borneo tidak diketahui, tetapi konversi kawasan hutan menjadi perkebunan monokultur dan kemungkinan adanya perburuan memiliki efek negatif bagi jenis ini. Sebagai jenis special daerah dataran tinggi-elevasi tinggi, perubahan iklim merupakan ancaman utama di masa yang akan datang. Suatu yang paling penting untuk jangka panjang bagi kelestarian jenis Biul Slentek ini adalah peningkatan pemahaman tentang status konservasi, ekologi dan ancaman sebenarnya (jika ada).

Abstrak (Bahasa Malaysia). Pulasan Lamri *Melogale everetti* merupakan antara karnivora paling kurang diketahui di Borneo dan kini tersenarai sebagai Kurang Maklumat (Data Deficient) di atas IUCN Red List of Threatened Species. Spesis ini endemik (hanya didapati) ke Borneo dan dikaitkan dengan hutan tanah tinggi di sekitar Taman Negara Kinabalu dan Taman Negara Banjaran Crocker. Kami berkumpul 52 rekod spesis ini di mana hanya 14 rekod dapat digunakan untuk menganggar potensi kesesuaian habitat. Spesis ini kemungkinan terhad kepada suatu kawasan kecil di barat Sabah dan oleh yang demikian, Pulasan Lamri mungkin memiliki julat taburan yang paling kecil antara semua spesis karnivora di Asia Tenggara. Semua rekod spesis ini melebihi 500m ketinggian dari paras laut dan ini menunjukkan spesis ini mungkin terhad kepada hutan tanah tinggi. Kawasan yang paling penting untuk memastikan pemuliharaan spesis ini adalah Taman Negara Kinabalu, Taman Negara Banjaran Crocker, serta kawasan yang tidak terlindung dan hutan simpanan untuk tujuan pembalakan di sebelah timur Taman Negara Banjaran Crocker. Oleh kerana kekurangan rekod terkini, ancaman utama terhadap spesis ini tidak diketahui, tetapi penukaran atau transformasi kawasan hutan asal kepada perladangan dan juga pemburuan, mungkin ada kesan negatif terhadapnya. Oleh kerana penyebarannya terbatas kepada hutan tanah tinggi, maka perubahan iklim mungkin juga akan menjadi satu ancaman pada masa depan. Yang paling penting bagi pemuliharaan Pulasan Lamri ialah meningkatkan pemahaman tentang status terkini, ekologi dan ancaman terhadapnya (jika ada).

INTRODUCTION

The Bornean ferret badger *Melogale everetti* (Thomas), is also known as Everett's ferret badger, Kinabalu ferret badger, or, in the main field guide to Borneo's mammals, simply ferret badger. It is one of four ferret badger species in the genus *Melogale* Geoffroy Saint-Hilaire, in South-east Asia. The species was described in 1895 by Oldfield Thomas and is endemic to the island of Borneo. The Bornean ferret badger (Fig. 1) has broad pelage variation from pale brown to dark brown with a paler underside (Wong et al., 2011). The Bornean ferret badger is listed as Data Deficient on The IUCN Red List of Threatened Species (Duckworth & Azlan, 2008) and little is known about its distribution and population status. It is known only from Gunung [=Mount] Kinabalu (Payne et al., 1985), Crocker Range Park (Wong et al., 2011; Ross et al., in press) and adjacent areas in the districts of Penampang, Tuaran and Tambunan, whence 57 museum specimens (Sabah Museum) were collected in the late 1960s–early 1970s (Wong et al., 2011). It is suspected also to occur on Gunung Tambayukon to the north of Kinabalu (Payne et al., 1985). There are no modern occurrence records outside this western Sabah mountain massif, and the only known evidence of its occurrence in other parts of Borneo is a subfossil record from the Niah Caves in Sarawak (Harrison, 1996). The 1991 sight-record by Boonratana (2010) from a tributary of the Sungai [=River] Kinabatangan, Sabah, remains questionable or rather unlikely, because the lower Kinabatangan is more than 200 km east of the other records, is in the extreme lowlands, and is one of the most comprehensively surveyed areas in the state, yet no subsequent records have emerged.

As with the distribution of the Bornean ferret badger, the species's ecology and habitat associations are largely unknown. Payne et al. (1985) noted that it is likely to eat earthworms and small vertebrates, and Dinets (2003) observed a Bornean ferret badger at a roadside rubbish dump at Kinabalu Park. Wong et al. (2011) caught a Bornean ferret badger in Crocker Range Park around Gunung Alab in a wire-mesh live-trap baited with banana. It is believed that the Bornean ferret badger, as other ferret badgers, is fossorial and likely to be nocturnal (Payne et al., 1985; Taylor et al., 1989; Ross et al., in press).

The Bornean ferret badger seems to be strongly associated with upland and highland forests and all confirmed records stem from between 500 and over 3000 m elevation (Borneo Carnivore Database; see Mathai et al., 2016). Camera-trapping in the southern portion of Crocker Range Park over altitudes from 380 to 1450 m recorded this carnivore on eight occasions, at three stations between 1080 and 1450 m (AJH, J Ross & DW Macdonald, unpublished data). The elevation of the Bornean ferret badger trapped on Gunung Alab was 1945 m (Wong et al., 2011). Griswold (in Allen & Coolidge, 1940) described the Bornean ferret badger as a "not very common, purely primeval-forest dweller" but the number of observations on which this description is based is unknown.

Fig. 1. Mounted museum specimen of a Bornean ferret badger *Melogale everetti* taken at the zoological collection of Sabah Parks. (Photograph by Andreas Wilting/IZW)

The species is currently listed, as protected, on the Sabah Wildlife Conservation Enactment 1997 as *Melogale personata* Geoffroy Saint-Hilaire (with which it was formerly often considered conspecific, including by Payne et al. (1985)), not as *Melogale everetti*. This listing needs to be updated, probably to the genus level, to avoid any legal loop-hole over the ambiguity of species names in current use for the taxon. The species is not protected in Sarawak, Brunei Darussalam or Indonesia, but it has not yet been recorded in any of these states. The species is not listed on CITES, but there is no evidence that it is traded.

RESULTS AND DISCUSSION

Species occurrence records. Of 52 records traced, 28 were excluded from modelling because their spatial precision was too low (over 5 km; Categories 4 and 5), whereas only seven records had high precision (within 2 km; Category 1) and only one record was collected within the last 10 years (Table 1, Fig. 2). All records were collected from Sabah, and because of spatial clumping only 14 were used for modelling (Table 1).

Habitat associations. The three respondents of the questionnaire were inconsistent in their assessment of suitable land-cover for the Bornean ferret badger (Table 2), reflecting how little is known about the species. Lowland areas, peat swamps and mangroves, young plantations, burnt and bare areas were considered generally unsuitable, whereas upper montane, upland forests and upland forest mosaics were ranked as the most important habitats.

Habitat suitability index (HSI) model. All occurrence records were from Sabah, thus we only applied the spatially filtered model M_2 (Kramer-Schadt et al., 2016). The spatial restriction of all known occurrence records to the western Sabah mountain massif and the habitat assessment resulted in a small predicted area of occurrence (Fig. 3). A large

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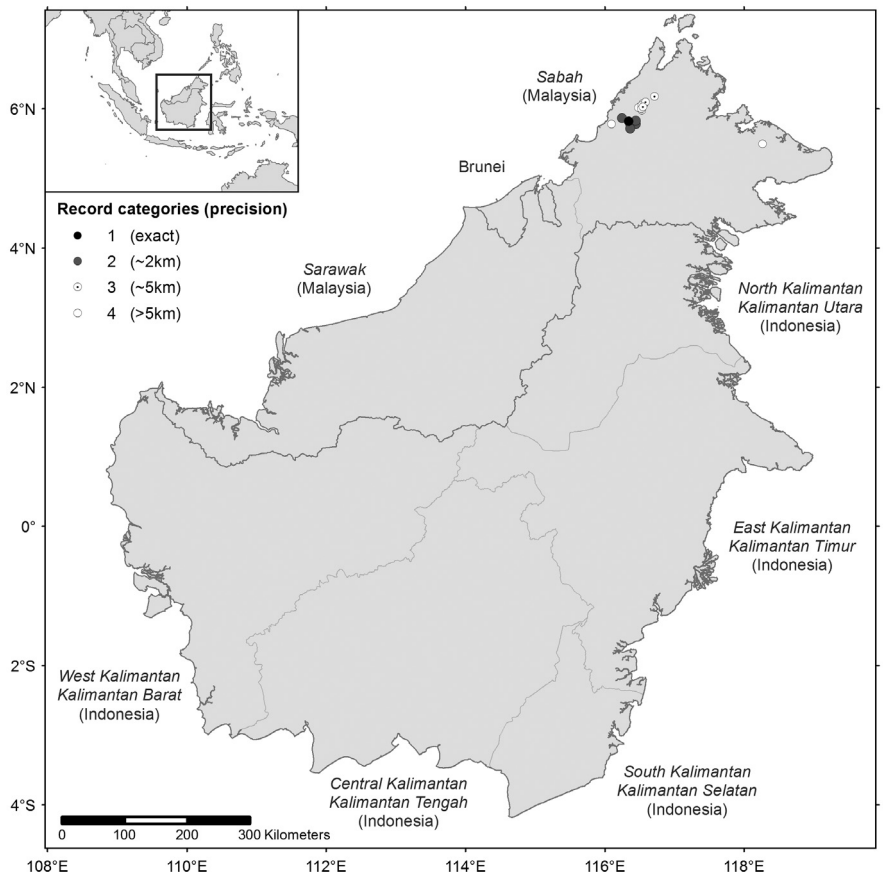

Fig. 2. Location of Bornean ferret badger *Melogale everetti* occurrence records in Borneo, showing categories of spatial precision as well as country and state boundaries.

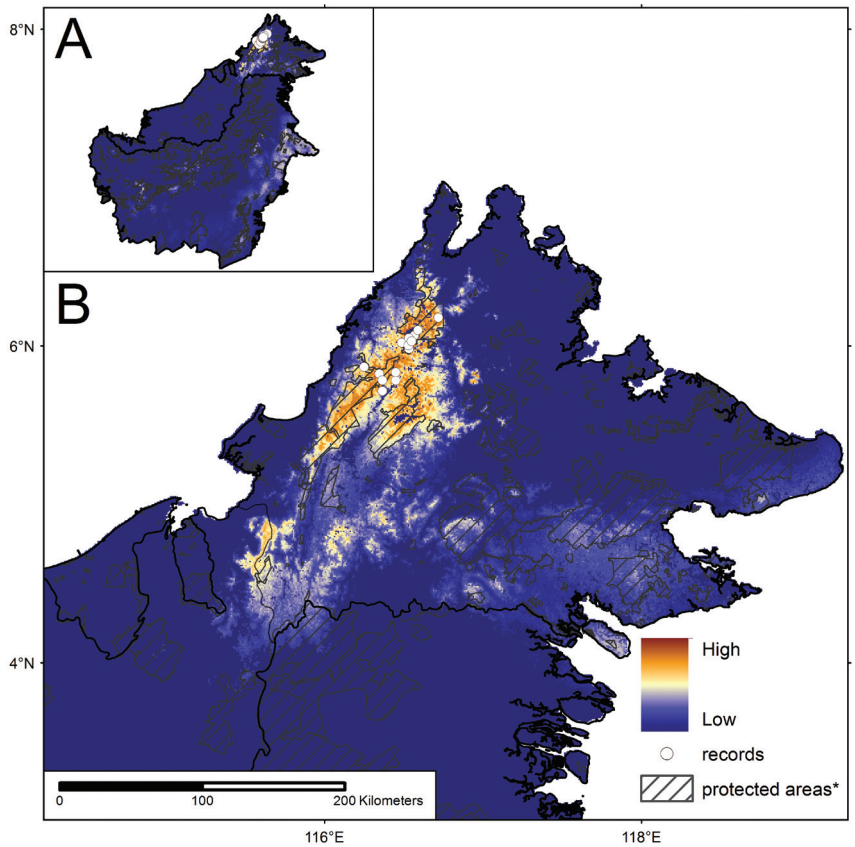

Fig. 3. Predicted habitat suitability index for Bornean ferret badger *Melogale everetti* including locality records used in models. Because records came only from Sabah, only the spatial filtering model was applied. A, predicted distribution across Borneo; B, enlargement of the predicted range across north-east Borneo. Sources for protected area information: see Kramer-Schadt et al. (2016).

Table 1. Summary of the occurrence records for Bornean ferret badger *Melogale everetti* 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	1	n/a	1	1
Category 2 500 m – 2 km	6	n/a	5	0
Category 3 2–5 km	17	n/a	8	2
Category 4 above 5 km	23	n/a	-	0
Category 5 (no coordinates*)	5	n/a	-	1
Total	**52**	**n/a**	**14**	**4**

M_1 = Balanced Model (not performed; all records came from Sabah); M_2 = Spatial Filtering Model (2 km); *only coarse location description was available.

Table 2. Land-cover reclassification for Bornean ferret badger *Melogale everetti* based on the questionnaire results of three respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	1.00	0–2
Upland forest	2.00	1–4
Lower montane forest	3.00	1–4
Upper montane forest	2.00	1–3
Forest mosaics/lowland forest	1.15	*
Forest mosaics/upland forest	1.63	#
Swamp forest	0.33	0–1
Mangrove	0.00	0–0
Old plantations	1.33	0–3
Young plantations and crops	1.00	0–3
Burnt forest area	0.67	0–2
Mixed crops	0.67	0–1
Bare area	0.00	0–0
Water and fishponds	0.33	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).

proportion of this predicted area is located within the two highland protected areas in west Sabah, Crocker Range Park and Kinabalu Park. In addition, unprotected areas and commercial forest reserves east and south of these protected areas are predicted to contain suitable habitat, although the suitability of these areas is likely to be inferior to that of the closer to pristine forests in the protected areas. Predicted areas of occupancy are congruent with previous assumptions based on known occurrence records that this species is endemic to the western Sabah mountain massif. However, surveys are necessary in mountainous regions of North Kalimantan and north-eastern Sarawak near the Sabah border to verify predicted distribution and allow, if any populations are found, appropriate conservation measures.

Sabah, Malaysia. As the Bornean ferret badger is plausibly endemic to the western Sabah mountain massif, all key sites for this species occur in the Malaysian state of Sabah. The two main sites for the species are Crocker Range Park and Kinabalu Park. The forests in these totally protected areas have the greatest probability to contain suitable habitat for the Bornean ferret badger. Further, unprotected areas east of these parks to the commercial forest reserves Trus Madi and Ulu Tungud are predicted to contain at least moderately

suitable habitats. However, the land between the parks and the forest reserves is one of the more densely populated areas in Sabah and is used largely for agriculture. Also, the Sipitang Forest Reserve and Maligan Virgin Jungle Reserve south of Crocker Range Park are predicted to contain at least marginally suitable habitat and further surveys in these areas would be useful to estimate the southern extent of the species's distribution range. Camera-trapping in Ulu Padas in the south of Sabah at 1050–1680 m a.s.l., a highly appropriate range in which to find the ferret badger if present in the area, did not record it (Brodie et al., 2015; JF Brodie in litt., 2015).

Sarawak, Malaysia. There is only subfossil evidence for the Bornean ferret badger from Sarawak, from the Niah caves (Harrison, 1996). Based on our predictions, the most likely areas in Sarawak to harbour Bornean ferret badger are in the north-east highlands of the Lawas district near the Sabah Border. These regions include Kanaya Forest Reserve, Long Semado, Long Remirang and Long Merarap and the forests around the headwaters of the Sungai Tengoa and the Sungai Berayong. No intensive wildlife surveys have been conducted in these areas. Surveys in other parts of Sarawak, including upland and montane areas in the Baram, did not record this species (Brodie et al., 2015; J. Mathai pers. comm., 2015).

Kalimantan, Indonesia. There is no evidence that the Bornean ferret badger occurs in Indonesia, but few intensive surveys have been conducted in the central Bornean mountain range so this species might occur and have been overlooked in Indonesia. Surveys in the northern end of Kayan Mentarang National Park in North Kalimantan near the Sabah border are recommended.

Brunei Darussalam. There is no evidence that the Bornean ferret badger occurs in Brunei and based on the predicted low habitat suitability, its presence is also rather unlikely.

RESEARCH PRIORITIES

Only one large camera-trapping effort has been conducted in the geographic and altitudinal range of the Bornean ferret badger, in Crocker Range Park. This study revealed much lower detection rates for the Bornean ferret badger than for similar-sized small carnivores (Ross et al., in press). Although there is no predictable relationship between detection rates and abundance when comparing across species, these data suggest that even within its core range, the species is rare and potentially occurs at low densities. In contrast to the Bornean ferret badger, other ferret badger species are camera-trapped frequently without the use of specialised protocols in parts of the Asian mainland (south-east China: Lau et al., 2010; Vietnam: Willcox et al., 2014: Table SOM3). Although this suggests lower abundances on Borneo, more intensive surveys are needed to evaluate the species's habitat associations and abundances. Particularly important are surveys outside totally protected areas to determine the adaptability of species to anthropogenic habitats. Such a study could be incorporated with the Kinabalu Ecolinc Project (http://www.sabahparks.org.my/discover-us/kinabalu-ecolinc-project), which intends to link Kinabalu Park and Crocker Range Park. The linkage zone between these parks contains forests and agricultural areas with many villages and the East–West Sabah highway traverses this ecological linkage. In May 2011, a Bornean ferret badger was observed crossing this road (JE pers. obs.), confirming that this species uses such degraded habitat. Further studies could reveal whether road causalities are also of concern, and also whether the species forages in such degraded habitat regularly, or merely wanders through it between forested areas. Therefore, this area provides a great framework for an intensive ecological study on the Bornean ferret badger. In addition to ecological studies, rapid surveys to assess occurrence, particularly in the east and south of the protected areas (both in the unprotected as well as commercially used forest reserves) are needed. Such surveys should also be expanded to the north-east highlands of the Lawas district, Sarawak, and to the northern part of Kayan Mentarang National Park, North Kalimantan.

THREATS AND CONSERVATION PRIORITIES

Overall, several potential threats plausibly threaten the Bornean ferret badger, but it is unclear if any are threats at the population level. Based on current understanding, the species's entire geographic range might be less than a few thousand square kilometres and comprise a single forest complex. This makes the Bornean ferret badger highly vulnerable to extinction from unpredictable events, such as epidemics or natural catastrophes. For Borneo, climate change is projected particularly to affect highland species such as the Bornean ferret badger as the potential for upslope range shifts is limited (Struebig et al., 2015). Although the habitat associations and the altitudinal range of the Bornean ferret badger are too poorly known to be sure that the recent widespread habitat change in its range and climate change pose an imminent threat, it is likely that this species is threatened by the ongoing land-cover transformation. There is no information on the potential effects of hunting. Trade of this species appears limited, but it is likely to be caught in non-selective traps (the Bornean ferret badger live-trapped using banana in Gunung Alab was a non-target capture; Wong et al., 2011).

That it is unknown whether several potential threats do adversely affect Bornean ferret badger populations highlights the poor understanding of this species and limits the design and application of species-specific conservation actions. Unless it is found to survive outside Sabah, all conservation efforts should focus on the western Sabah mountain massif. Restoring the ecological linkage between the two totally protected areas within the Kinabalu Ecolinc Project seems to be an important component in that it would maintain connectivity between the only two confirmed Bornean ferret badger populations. However, it is unknown if such a linkage is feasible, or if the land between the two sites is already too fragmented and degraded to be used habitually by the species.

The Bornean ferret badger is potentially one of the most threatened Bornean carnivores and warrants greater

conservation emphasis. Although the bay cat *Catopuma badia* (Gray), and Hose's civet *Diplogale hosei* (Thomas), are also endemic to Borneo, the estimated range of the Bornean ferret badger is much smaller than for either of these species. Further, the greater number of camera-trapping surveys in the last 10 years resulted in many more records of the Hose's civet and bay cat, whereas only one camera-trapping survey – in the Crocker Range – has found Bornean ferret badger (Ross et al. in press).

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