

Predicted distribution of the leopard cat *Prionailurus bengalensis* (Mammalia: Carnivora: Felidae) on Borneo

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

Abstract. The leopard cat *Prionailurus bengalensis* is one of the smallest cat species found on Borneo and is the most widely distributed wild cat species in Asia. It is listed on The IUCN Red List of Threatened Species as Least Concern. The leopard cat is known to tolerate habitat disturbance and to occur in a range of vegetation types including primary and secondary forests, plantations and orchards. However, the extent to which the leopard cat can tolerate habitat disturbance and utilise non-forest areas is still unknown. In this paper, we collected 373 leopard cat location records across Borneo; of these, 228 records were obtained between 2001 and 2011. We analysed 63 (Balanced Model) and 102 (Spatial Filtering Model) records to model habitat suitability. The models predicted more than two-thirds of Borneo to be suitable habitat for the leopard cat. Almost the entire area of Sabah, Sarawak, Brunei and East Kalimantan were predicted to be suitable. The south of Central Kalimantan and the majority of West Kalimantan were predicted to be marginally suitable whereas half of South Kalimantan was predicted to be unsuitable for this species. Although more intensive surveys in Brunei, West Kalimantan and South Kalimantan would help to understand leopard cat distribution, no conservation actions are needed for this species.

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

Abstrak (Bahasa Indonesia). Kucing Kuwuk *Prionailurus bengalensis* adalah salah satu jenis kucing liar terkecil yang ditemukan di Borneo dan merupakan jenis kucing liar yang sebarannya paling luas di Asia. Terdaftar sebagai jenis Berisiko Rendah (LC) pada Daftar Jenis Terancam Punah IUCN. Kucing Kuwuk diketahui sebagai jenis yang toleran terhadap habitat yang terganggu dan dapat hidup pada berbagai tipe hutan seperti hutan primer dan hutan sekunder serta lahan pertanian dan perkebunan. Namun sampai saat ini belum diketahui sejauh mana Kucing Kuwuk dapat bertahan terhadap gangguan habitat dan memanfaatkan kawasan bukan hutan. Pada penelitian ini kami mengumpulkan 373 catatan kehadiran Kucing Kuwuk di Borneo, 228 diantaranya merupakan catatan dari tahun 2001- 2011. Kami menganalisis 63 (Model Penyeimbang) dan 102 (Model Spasial Tersaring) catatan untuk membuat pemodelan kesesuaian habitat. Hasil pemodelan memprediksi lebih dari 2/3 dari Pulau Borneo sesuai untuk habitat Kucing Kuwuk. Hampir seluruh wilayah Sabah, Sarawak, Brunei, Kalimantan Utara dan Kalimantan Timur diprediksi sangat sesuai untuk habitat Kucing Kuwuk. Bagian Selatan Kalimantan Tengah dan sebagian besar Kalimantan Barat diprediksi sesuai untuk habitat Kucing Kuwuk, sedangkan sebagian Kalimantan Selatan diprediksi tidak sesuai untuk habitat jenis ini. Survey yang lebih intensif diperlukan untuk lebih memahami sebaran Kucing Kuwuk.

Abstrak (Bahasa Malaysia). Kucing Batu *Prionailurus bengalensis* merupakan antara spesis kucing liar terkecil terdapat di Borneo. Kucing ini juga merupakan spesis kucing yang mempunyai taburan yang paling luas di Asia. Ia disenaraikan di dalam Senarai Merah Spesis Terancam IUCN sebagai Kurang Membimbangkan. Kucing Batu diketahui mampu bertolak ansur dengan gangguan habitat dan dapat dijumpai di pelbagai jenis habitat termasuk hutan primer dan sekunder, kawasan ladang, dan kebun. Walaupun demikian, sejauh mana Kucing Batu ini mampu bertahan dalam habitat yang telah diganggu manusia dan menggunakan kawasan bukan hutan masih tidak diketahui. Dalam kajian ini, kami mengumpulkan 373 rekod lokasi di mana Kucing Batu dijumpai di Borneo. Daripada jumlah ini, 228 rekod diperolehi di antara tahun 2001–2011. Kami menganalisis 63 rekod (Model Seimbang) dan 102 rekod (Model yang ditapis secara spasial) untuk membina model kesesuaian habitat. Model yang dibina meramalkan lebih daripada dua pertiga kawasan Borneo sebagai habitat yang sesuai untuk Kucing Batu. Hampir keseluruhan kawasan Sabah, Sarawak, Brunei dan Kalimantan Timur diramalkan sebagai sesuai untuk Kucing Batu. Bahagian selatan Kalimantan Tengah dan sebahagian besar Kalimantan Barat diramalkan sebagai sederhana sesuai manakala separuh daripada Kalimantan Selatan diramalkan tidak sesuai untuk Kucing Batu. Penyelidikan yang lebih terperinci di Brunei, Kalimantan Barat dan Kalimantan Selatan akan membantu untuk memahami taburan Kucing Batu dengan lebih baik. Namun demikian, tiada sebarang tindakan pemuliharaan diperlukan untuk spesis ini.

INTRODUCTION

The leopard cat *Prionailurus bengalensis* (Kerr) is the most common wild cat species found in Asia. It has the widest distribution range of all Asian wild cats, ranging from southern India to the Russian Far East; Tsushima and Iriomote islands in Japan to Sumatra and Java in Indonesia. On Borneo, it occurs throughout the island. There is marked regional variation in pelage pattern (Sunquist & Sunquist, 2002). The leopard cat (Fig. 1) is among the smallest cats, with males tending to be larger than females (Rabinowitz, 1990). On Borneo, leopard cats are generally smaller (adult weights of 1.7-2.6 kg have been recorded (Rajaratnam, 2007; Najera et al., 2013)) than the global average, with animals elsewhere weighing up to 5 kg (Sunquist & Sunquist, 2002). The leopard cat is strictly carnivorous and primarily ground-dwelling. Studies carried out in Sabah and Thailand suggest that its preferred prey items are small mammals such as rodents, but it also feeds on reptiles, amphibians, birds and insects (Rabinowitz, 1990; Grassman, 2000; Grassman et al., 2005; Rajaratnam et al., 2007). Analysis of activity patterns from radio-tracking and camera-trap data have shown that leopard cats in Borneo are predominantly nocturnal (Rajaratnam et al., 2007; Ross et al., 2010; Mohamed et al., 2013) although in Thailand, they exhibited arrhythmic activity with nocturnal and crepuscular tendencies (Grassman, 2000; Grassman et al., 2005). Mean home range size for males in Sabah was 3.5 km² and for females was 2.1 km² (Rajaratnam et al., 2007). In Thailand, mean home range size for males was 4.1 km² and for females was 2.5 km² (Grassman, 2000). The leopard cat is known to tolerate habitat modification and disturbance well (Lim, 1999; Mohamed et al., 2013). Indeed, Mohamed et al. (2013) showed that leopard cat population density increased with forest disturbance. The species has also been reported in orchards (Lim, 1999) and oil palm plantations including forest patches within oil palm plantations located less than 1.7 km from the nearest forest-oil palm boundary (e.g., Rajaratnam et al., 2007; Silmi et al., 2013; Bernard et al., 2014; Yue et al., 2015; AJ Hearn, J Ross & DW Macdonald, unpublished data), although its presence in such habitats might still depend on proximity to more natural habitat types, and its ability to venture deep into plantations remains unknown (Bernard et al., 2014).

Because of its wide geographic range and relatively high abundance (Nowell & Jackson, 1996), as well as its ability to persist in altered habitat, the leopard cat is classified as Least Concern by The IUCN Red List of Threatened Species (Sanderson et al., 2008). Although the species has been extensively hunted for fur in China (Yu, 2010), populations



Fig. 1. Leopard cat *Prionailurus bengalensis* camera-trapped in Tangkulap Forest Reserve, Sabah, Malaysian Borneo, on 27 February 2009. (Photograph by: A. Mohamed & A. Wilting/IZW, SFD, SWD).

are believed to be relatively stable in other parts of its range. Despite this, Mohamed et al. (2013) reported population densities of 9.6 to 16.5 individuals/100 km² which is relatively low for a small cat. The leopard cat is listed in Appendix II of CITES to which treaty all three countries comprising Borneo are parties. At the national level, the leopard cat is legally protected from hunting under the Sarawak Wild Life Protection Ordinance (1998) and the Appendix of The Government of Republic of Indonesia Regulation No. 7 (1999). The leopard cat is also legally protected in Sabah under the Sabah Wildlife Conservation Enactment (1997) although hunting or collection of this species is allowed under license from the authorities. In Brunei, this species is not legally protected.

RESULTS AND DISCUSSION

Species occurrence records. Of 373 location records from Borneo, 228 were collected between 2001 and 2011 (Table 1). Almost half the records, 184, were spatially precise to within 2 km (Category 1) but 76 were excluded from modelling because of low precision (over 5 km; Categories 4 and 5). Records came from all three countries in Borneo but most were from the Malaysian state of Sabah, especially its north-eastern part (Fig. 2) where studies have been highly concentrated. No precise records were obtained from the south-east of Sarawak and eastern West Kalimantan. To reduce survey-effort bias, the modelling process (see Kramer-Schadt et al., 2016) used 63 (Balanced Model = M₁) or 102 (Spatial Filtering Model = M₂) records.

Habitat associations. The 14 respondents of the questionnaire classifying land-cover suitability for the leopard cat were inconsistent in their assessments (Table 2), perhaps reflecting the broad range of habitats in which the species has been recorded. Most respondents agreed that lowland forest, forest mosaics (lowland and upland) and old plantations were the most suitable habitats, whereas upland, lower montane forest, swamp forest and young plantations and crops were ranked as only marginally suitable. Bare areas, water and fishponds, and water were ranked as the least suitable. However, for some categories, such as upper montane forest, swamp forest

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Table 1. Summary of the occurrence records for the leopard cat *Prionailurus bengalensis* 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	184	23	42	183
Category 2 500 m – 2 km	29	7	11	16
Category 3 2–5 km	84	33	49	15
Category 4 above 5 km	44	–	–	10
Category 5 (no coordinates*)	32	–	–	4
Total	373	63	102	228

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

Table 2. Land-cover classification for the leopard cat *Prionailurus bengalensis* based on the questionnaire results of 14 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.57	2–4
Upland forest	2.82	1–4
Lower montane forest	2.09	1–4
Upper montane forest	1.36	0–4
Forest mosaics/lowland forest	3.42	*
Forest mosaics/upland forest	3.04	#
Swamp forest	2.25	0–4
Mangrove	1.58	0–4
Old plantations	3.27	2–4
Young plantations and crops	2.08	1–3
Burnt forest area	1.33	0–3
Mixed crops	1.42	0–3
Bare area	0.08	0–1
Water and fishponds	0.25	0–2
Water	0.08	0–1

*/#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).

and mangrove, classification ranged from 0 (unsuitable) to 4 (very suitable). Generally, these results indicated that the respondents believe most land-cover categories to be suitable for the leopard cat, at least to some level. This habitat assessment together with the location records was used to inform the habitat suitability model (see Kramer-Schadt et al. (2016) for methods), which predicted most of Borneo, including plantations, to be suitable habitat for the species (Fig. 3).

Habitat suitability index (HSI) model. With large parts of Borneo predicted to be suitable habitat for the leopard cat, we do not recommend any special conservation measures for the species. Because of its wide distribution and commonness,

selection of key conservation areas is also not necessary at the moment.

Brunei Darussalam. A large proportion of Brunei Darussalam remains covered by natural forest and almost the whole of the country is predicted to be suitable habitat for the leopard cat. However, it is surprising that for a common species, we obtained only one record from Brunei, which was from Ulu Temburong National Park; the only national park in this country. There was another record obtained from the border of Labi Forest Reserve (Brunei) and Mulu National Park (Sarawak). It is likely that the low number of records is not a result of a range restriction of the leopard cat in Brunei, but is rather a result of the lower number of

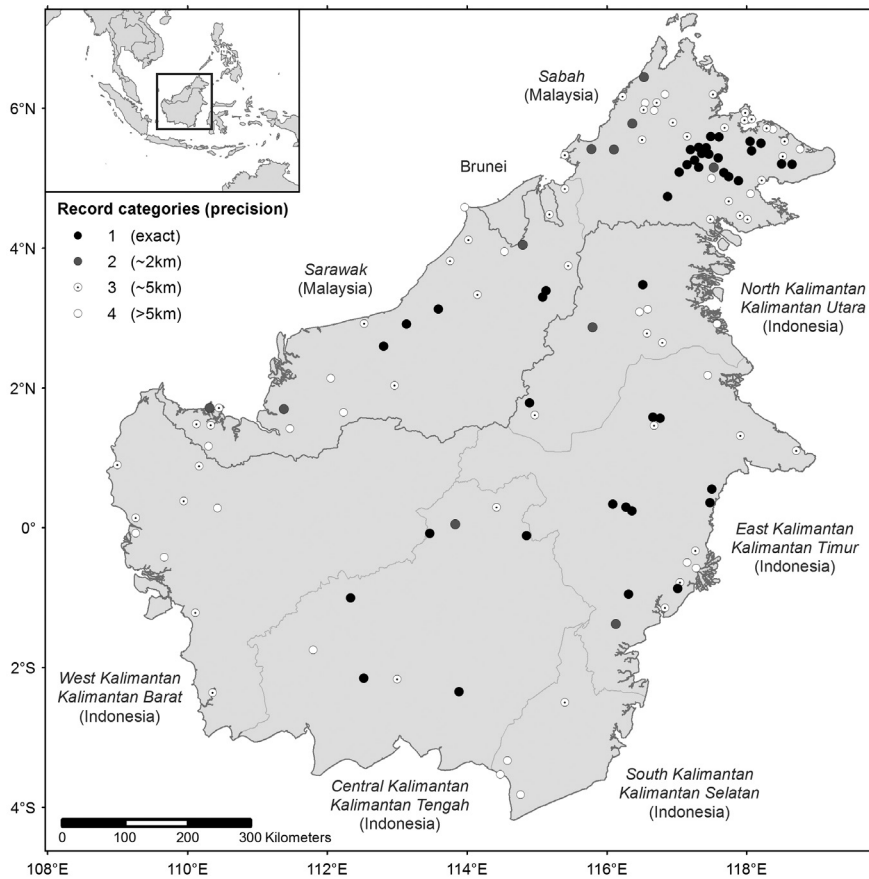


Fig. 2. Location of leopard cat *Prionailurus bengalensis* occurrence records on Borneo with categories of spatial precision as well as countries and state boundaries.

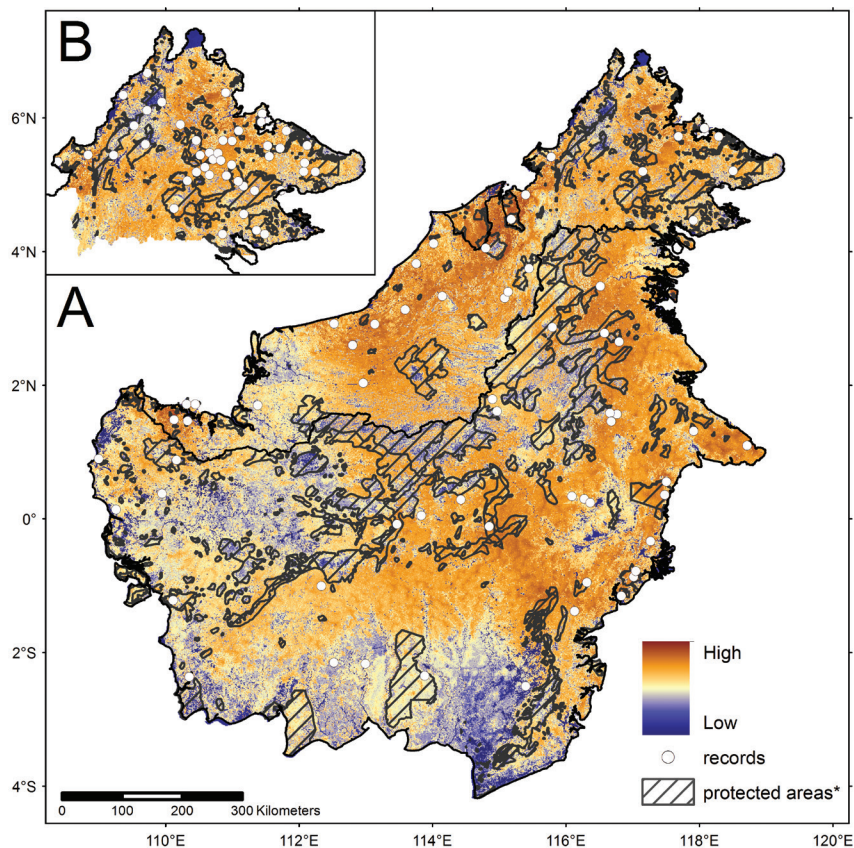


Fig. 3. Predictive Habitat Suitability Index (HSI) models for the leopard cat *Prionailurus bengalensis* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et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

surveys in this country. Therefore as with other, including more threatened carnivores, more surveys in Brunei would help greatly to understand the distribution of the leopard cat in this country. It is very likely that the leopard cat occurs also outside the Ulu Temburong National Park and the other four forest reserves (FR) namely Bukit Ladan FR, Labi FR, Peradayan FR and Andulau FR in Brunei. Despite the lower number of studies it is also plausible that the peat swamp forests and heath forests of Brunei might also be less suitable for the species. Further, it is known that leopard cat density decreases in better forest conditions (e.g., Mohamed et al., 2013), so the generally more natural forests in Brunei might support only lower leopard cat numbers than do the disturbed forests with neighbouring oil palm plantations in other areas of Brunei.

Sabah, Malaysia. The majority of Sabah is predicted to be suitable habitat for the leopard cat except some parts of the coastal areas and Kinabalu National Park with its high elevation. About 60% of Sabah still remains under some form of forest cover. Although large tracts of forest especially in the lowlands have been converted to oil palm plantations, these areas are predicted to be suitable habitat for the leopard cat, and indeed there have been frequent sightings in plantations (see below). The central forest block in Sabah, the largest contiguous forest area in the state and comprising Danum Valley, Maliau Basin, and Imbak Canyon Conservation Areas and vast areas of surrounding logging concession, is also predicted to be very suitable for the leopard cat. Recent camera-trapping in these logging concession has confirmed leopard cat occurrence throughout this area (e.g., Mohamed et al., 2009; Ross et al., 2010; Samejima et al., 2012; Bernard et al., 2013). In eastern Sabah, Tabin Wildlife Reserve, Lower Kinabatangan Wildlife Sanctuary and the surrounding oil palm plantations are predicted to be suitable. Further research would allow clarification of the extent to which the leopard cat relies on forested patches to survive in oil palm plantations.

Sarawak, Malaysia. As with Sabah, the majority of Sarawak is predicted to be suitable habitat for the leopard cat, including the extensive areas of oil palm plantation, largely along the coastal region. Despite these predictions and the extensive camera-trapping in Sarawak, only very few leopard cat camera-trap records were obtained. Interestingly, most records were outside national parks or protected areas (e.g., Gimán et al., 2007; McShea et al., 2009; Mathai et al., 2010), which might support the assumption that the leopard cat occurs in higher densities in more disturbed forests (Mohamed et al., 2013).

East Kalimantan and North Kalimantan, Indonesia. The majority of the area of East and North Kalimantan was predicted to be suitable habitat for the leopard cat. However, large parts are not protected and are under pressure to be converted to oil palm plantations. The largest protected area in Borneo, Kayan Mentarang National Park in North Kalimantan (approx. 1.36 million ha), which provides transboundary highland connectivity with forest in Sarawak, was predicted to be of low suitability for the leopard cat.

Probably, this reflects its mostly high-elevation mountainous topography. Although the leopard cat has been recorded on Borneo up to higher elevations (see Mathai et al., 2014, 2016; B. Loken, unpublished data), most records are from lowland areas, which is likely to have resulted in the lower suitability prediction. In contrast to the Kayan Mentarang National Park, the lowland Kutai National Park in East Kalimantan and its surrounding areas were predicted to be highly suitable.

South Kalimantan, Indonesia. Most of South Kalimantan was predicted to be less suitable for the species. But South Kalimantan is more seasonal than the rest of Borneo, and it is likely that these different bioclimatic conditions resulted in a lower prediction of suitable habitat, particular because no precise occurrence record of the leopard cat was available to be included in the modelling. The low number of records from South Kalimantan is most likely to be a reflection of low survey effort; more surveys would allow a clearer evaluation of leopard cat distribution, and that of more threatened carnivores, in this province.

Central Kalimantan, Indonesia. From the predictive species distribution modelling, inland Central Kalimantan, particularly the north-eastern part, was predicted to be moderately suitable. The area, which shows the highest suitability is not legally protected, as with other areas of Borneo predicted to be highly suitable. The mountainous Bukit Baka – Bukit Raya National Park and the proposed Gunung Müller National Park were predicted to be only marginally suitable habitat for the leopard cat. The extensive peat swamp forests in the southern part of the province were predicted to be poor or marginally suitable although several individuals have been camera-trapped recently in Sabangau peat swamp forest (Cheyne & Macdonald, 2011).

West Kalimantan, Indonesia. The majority of West Kalimantan was predicted to offer unsuitable or marginally suitable habitat for the leopard cat. However, this is probably because the distribution was predicted from only a few records from West Kalimantan, and thus may not reflect the true situation. This indicates clearly that a better understanding of leopard cat distribution in West Kalimantan requires more intensive surveys there. The area with the highest habitat suitability index was the eastern part of the province and outside Betung Kerihun National Park.

GENERAL CONSERVATION PRIORITIES

The leopard cat is still widely distributed in Borneo, and uses various habitat types including forest, oil palm and rubber plantations. Because of its wide distribution and general indications that it is common, the leopard cat is a species of low conservation concern. In Sabah, Mohamed et al. (2013) found that overall leopard cat densities might be lower than expected, but that they increased with forest disturbance. This was partly supported by the modelling in this study: many areas predicted to be highly suitable were located outside protected areas, often in commercially exploited forests. This resilience is uncommon among tropical rain-forest carnivores

(Meijaard et al., 2008). Despite records of leopard cats in oil palm plantations (Rajaratnam et al., 2007; Silmi et al., 2013; Yue et al., 2015; AJ Hearn, J Ross and DW Macdonald, unpublished data) it is not yet known in detail how leopard cats use non-forested areas. It is plausible that these areas are used for hunting because of high prey abundance (such as rats), but the leopard cat might perhaps still require forest to fulfil other needs such as shelter or denning. Therefore a better understanding remains warranted of the extent and types of leopard cat use of non-forested areas, and the level of their tolerance toward habitat disturbance.

ACKNOWLEDGEMENTS

We would like to thank Miyabi Nakabayashi, Rob Stuebing, Yoshishiro Nakashima, Anjar, John Howes, Roger Wilkinson, Godwin Limberg, Vladimir Dinets, Lim Boo Liat, Sophie Persey, Sander Pieterse, Ben Wielstra, Tjalle Boorsma, Amanda Peter and Shai Meiri for contributing occurrence records for this species.

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