

Predicted distribution of the yellow-throated marten *Martes flavigula* (Mammalia: Carnivora: Mustelidae) on Borneo

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

Abstract. The yellow-throated marten *Martes flavigula* is a wide-ranging species across much of Asia. It is active mainly during the day, is semi-arboreal and has an omnivorous diet. On Borneo, it has a wide elevation range, from coastal lowland to lower montane habitat of 1700 m a.s.l. Records from camera-trapping and other wildlife surveys imply a widespread distribution, but the species is encountered less frequently than in many other parts of its global range. We collected a total of 195 occurrence records from all political units of Borneo except South Kalimantan. To reduce possibly confounding effects of sampling bias on habitat suitability we used 56 records in a Balanced Model and 94 records in a Spatial Filtering Model. Respondents' opinions on habitat preference showed large variation, except for lowland and upland dipterocarp forests, which were consistently perceived as highly suitable; disturbed areas such as burnt forests and bare areas were perceived to be less favourable. The habitat suitability model predicted that the yellow-throated marten is widespread within Borneo, likely to occur in mosaics of lowland and upland forests, including old plantations and active logging areas; but unlikely to use young plantations and crops, perhaps including oil palm plantations. The effects of logging on yellow-throated marten are not well understood, yet the species's population size on Borneo will depend on how tree plantations and logging concessions are managed and harvested. More surveys above about 1200 m a.s.l., where information is still limited, would enable more confident habitat assessments. Further research could determine if the Bornean subspecies, *M. f. saba*, could be a cryptic species.

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

Abstrak (Bahasa Indonesia). Musang Leher-Kuning *Martes flavigula* merupakan jenis yang tersebar luas, meliputi hampir semua benua Asia. Umumnya aktif di siang hari, semi-arboreal dengan sifat makan omnivorous. Di Borneo, kisaran ketinggian wilayah sebarannya sangat lebar, dari mulai pesisir dataran rendah hingga pegunungan dataran rendah pada ketinggian 1700 m dpl. Dari tingkat terekamnya lewat perangkap kamera dan survey lapang menunjukkan persebaran yang luas, namun cenderung terpantau dalam frekuensi yang rendah. Kami telah mengumpulkan 195 catatan keberadaan dari semua wilayah, terkecuali Kalimantan Selatan. Untuk menurunkan kesan pembauran akibat persampelan bias, 56 catatan dari Model Penyeimbang dan 94 catatan dari Model Spasial Tersaring digunakan dalam pemodelan kesesuaian habitat. Pendapat responden terhadap pemilihan habitat menunjukkan variasi yang lebar, terkecuali untuk wilayah hutan dipterocarpa dataran rendah dan tinggi, di mana secara konsisten mendapatkan penilaian yang tinggi; serta wilayah terganggu seperti hutan bekas terbakar dan area terbuka sebagai wilayah yang kurang diminati. Hasil pemodelan kesesuaian habitat kami memperkirakan bahwa persebaran Musang Leher-Kuning tersebar di seluruh Borneo, terlebih pada pilahan hutan di daerah dataran rendah dan tinggi, termasuk daerah dengan tumbuhan tua dan penebangan aktif; namun tidak begitu banyak dijumpai di wilayah dengan tumbuhan muda atau perkebunan, termasuk perkebunan sawit. Pengaruh dari penebangan hutan terhadap keberadaan Musang Leher-Kuning masih belum dipahami dengan baik di Borneo, keberadaannya tergantung dari bagaimana wilayah perkebunan dan kehutanan dikelola dan dipanen. Survey lebih lanjut dibutuhkan pada ketinggian diatas 1200 m dpl, dimana informasi masih jarang, sehingga pemodelan kesesuaian habitat dapat dilakukan dengan lebih meyakinkan. Kami juga mengidentifikasi perlunya penelitian lebih lanjut untuk menetapkan apakah anak jenis *M. f. saba*, dimana terekamnya lewat perangkap kamera lebih jarang dibandingkan dengan kisaran global, merupakan jenis yang kriptik.

Abstrak (Bahasa Malaysia). Mengkira/Musang Leher-Kuning, *Martes flavigula* merupakan spesies yang tersebar luas yang boleh dijumpai di kebanyakan kawasan di benua Asia. Ia aktif pada waktu siang, separa arboreal dan bersifat omnivor. Di Borneo, ia boleh ditemui di pelbagai ketinggian, bermula dari hutan tanah pamah sehingga hutan tanah tinggi, pada paras ketinggian 1700 m dari aras laut. Kekekapan rekod yang diperolehi daripada perangkap kamera dan tinjauan lapangan menunjukkan ia mempunyai taburan yang meluas di Borneo, namun ditemui dalam frekuensi yang jauh lebih rendah berbanding kebanyakan kawasan lain di dunia. Kami telah mengumpulkan 195 rekod dari kesemua daerah politik di Borneo kecuali Kalimantan Selatan. Untuk mengurangkan kemungkinan kesan pembauran (confounding effects) akibat daripada persampelan yang tidak seragam terhadap kesesuaian habitat, kami menggunakan 56 rekod di dalam pendekatan Model Seimbang dan 94 rekod di dalam pendekatan model yang ditapis secara spasial. Pandangan daripada responden tentang kecenderungan pemilihan habitat menunjukkan variasi yang

tinggi, kecuali di kawasan hutan dipterokap tanah pamah dan tanah tinggi yang secara konsisten menunjukkan habitat yang sangat sesuai; dan kawasan yang terganggu seperti hutan yang mengalami kebakaran dan kawasan lapang didapati kurang sesuai. Model kesesuaian habitat kami meramalkan taburan Mengkira tersebar di seluruh Borneo, mungkin terdapat di kawasan mozek hutan tanah pamah dan tanah tinggi, termasuk kawasan penanaman lama dan kawasan pembalakan aktif; namun kemungkinan tidak dijumpai di kawasan penanaman baru dan perladangan, yang mungkin termasuk ladang kelapa sawit. Kesan pembalakan terhadap Mengkira masih belum difahami secara mendalam di Borneo, namun kewujudannya akan bergantung kepada bagaimana ladang pokok kayu dan konsesi pembalakan diurus dan dibalak. Lebih banyak penyelidikan diperlukan di kawasan yang ketinggiannya melebihi 1200 m dari aras laut, kerana pengetahuan masih terhad untuk membolehkan penilaian habitat dilakukan dengan yakin. Kami mencadangkan penyelidikan lanjut untuk menentukan sama ada subspesies Borneo, *M. f. saba*, yang jarang direkodkan dari perangkap kamera berbanding kawasan lain di dunia, berkemungkinan satu spesies yang kriptik.

INTRODUCTION

The yellow-throated marten *Martes flavigula* (Boddaert), has a wide range from eastern Afghanistan to the Russian Far East, extending south to the Malaysian peninsula, Sumatra, Java and Borneo (Corbet, 1978; Corbet & Hill, 1992). This species is classified within the family Mustelidae, a family of small to medium sized carnivores (Corbet & Hill, 1992). Apart from marginal occurrence of Beech Marten *M. foina* (Erxleben) in North Myanmar (Than Zaw et al., 2008), yellow-throated marten (Fig. 1) is the only marten in South-east Asia (Kanchanasakha et al., 1998). The IUCN Red List of Threatened Species classifies the yellow-throated marten as Least Concern (Abramov et al., 2008).

In Borneo, yellow-throated marten weighs from 1000 to 1370 g, has a head and body length of 403–463 mm, and a tail about 75% of the head and body length (Payne et al., 1985). The upperparts are brown to pale brown anteriorly but dark brown posteriorly. The yellowish or buff chin, throat and chest are conspicuous. The tail is dark brown, sometimes with a pale tip. It can be confused, particularly on poor quality camera-trapping images, with collared mongoose *Herpestes semitorquatus* (Gray), which has a yellow neck pattern but more pointed muzzle and a shorter tail.

Yellow-throated marten is active mainly during the day (Payne et al., 1985; Corbet & Hill, 1992). Camera-trapping in Sumatra, Indonesia, indicated a crepuscular activity pattern (van Schaik & Griffiths, 1996), but in Kalimantan (Cheyne et al., 2010) and Sabah (Bernard et al., 2013; Ross et al., in press), records came predominantly from dawn to dusk. It is semi-arboreal (Payne et al., 1985; Corbet & Hill, 1992) and has been observed in the mid- and upper canopy (Mathai et al., 2010; Wilting et al., 2010).

Across its world range, its diet includes fruit, nectar, ‘honey’ (perhaps mainly or solely bee larvae) and a wide range of small vertebrates and invertebrates (Pocock, 1941; Lekagul & McNeely, 1977; Payne et al., 1985). Faecal analysis of Chinese animals revealed that fruits were commonly consumed when available, with greater use of species with fruits over 50% pulp and/or very sweet (Zhou et al., 2008). Habituated individuals at Khao Yai National Park were observed eating cooked rice placed by people (Parr & Duckworth, 2007). Parr (2003) generally categorised it as having a “diverse, omnivorous diet”.

Along with its wide distribution, yellow-throated marten inhabits a wide spectrum of habitats. In Borneo, it occurs in tall and secondary forests, and often enters plantations and gardens in search of food (Payne et al., 1985). The species was recorded in both components of acacia plantation-secondary forest mosaics (Belden et al., 2007; Rustam et al., 2012). In peninsular Malaysia, it was camera-trapped inside a secondary forest surrounded by oil palm plantations (Azlan, 2003). It has been recorded travelling along main roads and trails (Grassman et al., 2005) and within 10 m of a road (Austin & Tewes, 1999), both inside protected mixed evergreen forests.

Yellow-throated marten had been recorded as solitary animal (see Belden et al., 2007; Mathai et al., 2010), but many observations are of groups of two, three or more (Payne et al., 1985; Duckworth, 1997; Sathyakumar, 1999; Grassman et al., 2005; Parr & Duckworth, 2007; Than Zaw et al., 2008; Hedges et al., 2013), and this may be usual, given the difficulties of observing animals in dense forested habitats.

In Borneo, yellow-throated marten is recorded from various habitat types over a wide elevation range. It was recorded throughout the lowlands and hills including Gunung [=Mount] Kinabalu, the Crocker Range, Sepilok and Tawau in Sabah, the Kelabit Highlands, Samunsam and other sites in Sarawak, Gunung Palung in West Kalimantan, Kotawaringan in Central Kalimantan, Teluk Pamukan in South Kalimantan, and Peleben and Kayan Mentarang National Park in East Kalimantan (Payne et al., 1985; Augeri, 2005). In Brunei, it was recorded from Bukit Tudal (Yasuma & Abdullah, 1997). More recent records stem from Maliau Basin (Brodie & Giordano, 2011) and Deramakot Forest Reserve (Matsubayashi et al., 2007; Wilting et al., 2010), Imbak

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Fig. 1. Yellow-throated marten *Martes flavigula* camera-trapped in Deramakot Forest Reserve, Sabah, Malaysia on 20 November 2014 (Photograph by: A. Mohamed/IZW, SFD).

Canyon Conservation Area, Danum Valley, Ulu Segama Forest Reserve, Malua Forest Reserve, Tabin Wildlife Reserve, Kinabatangan, and Crocker Range Park (Bernard et al., 2013, 2014; Ross et al., in press) in Sabah; the upper Baram (Mathai et al., 2010) and Samarakan (Belden et al., 2007) in Sarawak; Sabangau peat swamp forest (Cheyne et al., 2010) and upper Seruyan in Schwaner mountains (Samejima & Semiadi, 2012) in Central Kalimantan; and Bukit Soeharto Grand Forest Park in East Kalimantan (Rustam et al., 2012).

Yellow-throated marten has been recorded from 10 m a.s.l. in lowland peat swamp and mixed dipterocarp forest (Duckworth, 1995; Cheyne et al., 2010) to 1452 m a.s.l. in Crocker Range (AJ Hearn, J Ross & DW Macdonald, unpubl. data), 1500 m a.s.l. in the Kelabit Highlands and 1700 m a.s.l. at Gunung Kinabalu (Payne et al., 1985), with the vegetation at this altitude resembling lower montane forest (Kitayama, 1992). As well as primary forest, it has been found in areas with logging, shifting cultivation and hunting (Mathai et al., 2010), and in logged-over forest of various ages since last logging operations (see Mathai et al., 2010; Wilting et al., 2010; Brodie & Giordano, 2011; Samejima & Semiadi, 2012; Samejima et al., 2012; Bernard et al., 2013; Ross et al., in press). Records in oil palm plantations were adjacent to large continuous tracts of native forest (Bernard et al., 2014; Ross et al., in press; Yue et al., 2015). Therefore, it might not permanently stay in oil palm habitat.

Frequencies of records obtained from camera-traps and wildlife surveys in Borneo imply that this species is quite widespread and regularly encountered, but at generally lower frequencies than are often found in other parts of its global range. It is more commonly and widely camera-trapped or otherwise encountered across its non-Sundaic South-east Asia range in Thailand (Chutipong et al., 2014), Vietnam (Willcox et al., 2014: Table SOM3), Lao PDR (Duckworth, 1997; Johnson et al., 2009; Coudrat et al., 2014), Cambodia (Holden & Neang, 2006; Gray et al., 2014), Sumatra (Holden, 2006) and Myanmar (Tan Zaw et al., 2008).

RESULTS AND DISCUSSION

Species occurrence records. In total, 195 records were collected, of which 156 were precise to within 5 km, and 106 were collected between 2001 and 2011 (Fig. 2, Table 1). After filtering the records to reduce negative effects of uneven search effort, 56 (Balanced Model) and 94 records (Spatial Filtering Model) were used for modelling potential habitat suitability (see Kramer-Schadt et al. (2016) for methods).

Habitat associations. Based on respondents' opinions, this species occurs over diverse habitats, ranging from lowland dipterocarp forests to possibly the lower fringe of upper montane forests (Table 2). It is thought likely to occur in forest mosaics of lowland and upland forests, including old plantations but not in young plantations and crops, which may also include oil palm plantations. Disturbed areas such as burnt forests and mixed crop areas are perceived to be less favoured. Apart from lowland and upland forests for which respondents generally agreed in their assessment, there was little consistency for most other habitats amongst respondents.

Habitat suitability index (HSI) model. The habitat suitability modelling suggests that the yellow-throated marten is widespread within Borneo (Fig. 3). This map needs to be interpreted with caution (see Kramer-Schadt et al. (2016) for more details). Some areas, particularly in South and West Kalimantan, had little information, reflecting lower survey effort. Although such 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 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. 3A).

Brunei Darussalam. Brunei maintains substantial near-intact lowland forest, some areas of which are connected to Sarawak, although forests in the latter have largely been opened up for logging and converted to other land uses. Almost all Brunei is predicted to be highly suitable. There are no major threats known so far, only reports of small-scale illegal hunting not targeted at yellow-throated marten. This species is not listed in the Wild Life Protection Act of Brunei, 1981.

Sarawak, Malaysia. Much of Sarawak is predicted to be suitable, except higher elevations pending more information. A lot of the area predicted suitable is subjected to logging and tree plantation (see later part of Discussion). This species is not protected in the Sarawak Wild Life Protection Ordinance 1998.

Table 1. Summary of the occurrence records for yellow-throated marten *Martes flavigula* 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	79	19	38	79
Category 2 500 m – 2 km	17	9	12	10
Category 3 2–5 km	60	28	44	8
Category 4 above 5 km	25	–	–	3
Category 5 (no coordinates*)	14	–	–	6
Total	195	56	94	106

M₁ = Balanced Model; M₂ = Spatial Filtering Model (5 km);
 *only coarse location description was available.

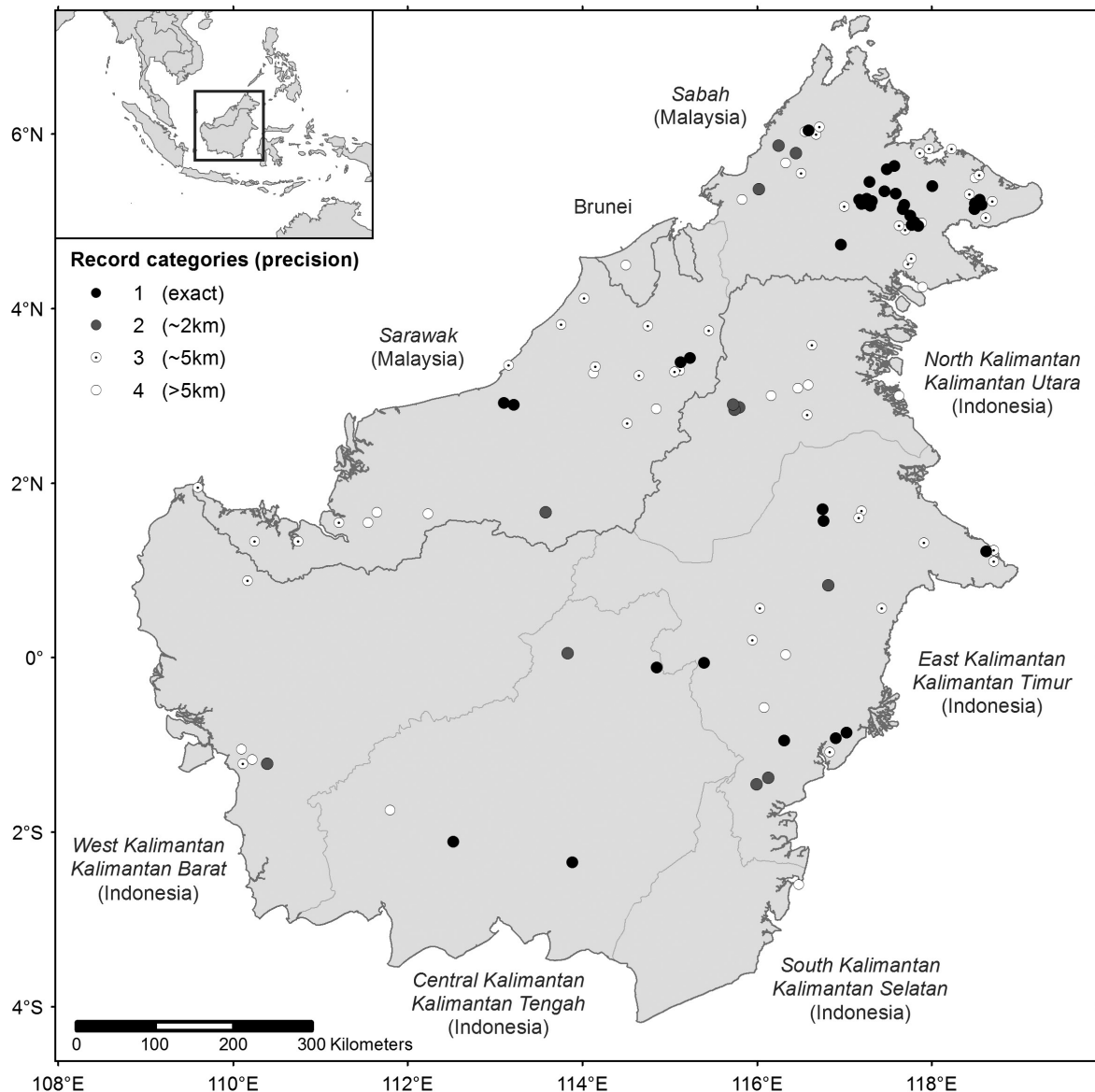


Fig. 2. Location of yellow-throated marten *Martes flavigula* occurrence records in Borneo, showing categories of spatial precision as well as country and state boundaries.

Table 2. Land-cover reclassification for yellow-throated marten *Martes flavigula* based on the questionnaire results of 12 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.58	3–4
Upland forest	3.33	2–4
Lower montane forest	2.67	1–4
Upper montane forest	2.00	0–4
Forest mosaics/lowland forest	2.96	*
Forest mosaics/upland forest	2.85	#
Swamp forest	2.30	0–4
Mangrove	1.11	0–3
Old plantations	2.44	1–4
Young plantations and crops	1.00	0–2
Burnt forest area	0.60	0–3
Mixed crops	0.80	0–3
Bare area	0.00	0–0
Water and fishponds	0.10	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).

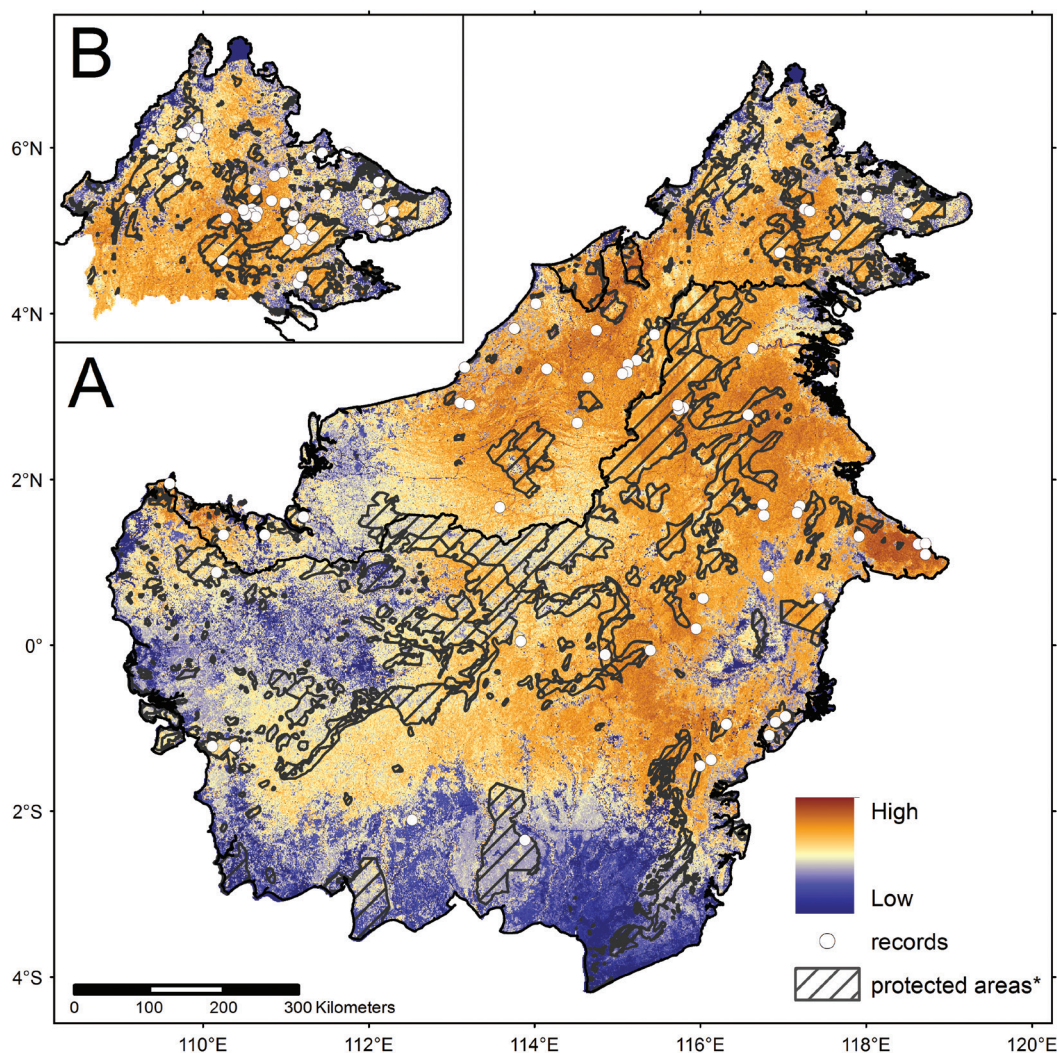


Fig. 3. Predictive Habitat Suitability Index (HSI) models for yellow-throated marten *Martes flavigula* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al.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

Sabah, Malaysia. Sabah provided the highest number of records, perhaps because of its high prevalence of wildlife research. Almost all Sabah is predicted to be suitable, except the coastal region and lowland regions converted to oil palm plantations. The contiguous lowland forest of Danum Valley and Imbak Canyon Conservation Areas are highly suitable. Some of these areas are within logging concessions, such as the Deramakot Forest Reserve and the Yayasan Sabah Forest Management Area. Yellow-throated marten is protected under Schedule 2 Part I of the Sabah Wildlife Enactment 1997, whereby only limited hunting and collection is permitted, and only upon the issuance of license.

Kalimantan, Indonesia. The five provinces of Kalimantan, Indonesia, cover approximately two-thirds of the island of Borneo. Most of the lowland area is unprotected or degraded and faces high risk of degradation and conversion, mainly driven by economic development pressures and recurrent fires. Large parts of the upstream forest areas are still in relatively good condition. A large road network called Trans Kalimantan is proposed to connect the North Kalimantan coast to West Kalimantan, cutting across the interior highlands and Kayan Mentarang National Park, and connecting to the coast of Sarawak along the way. Such massive development will catalyse fragmentation of currently forested areas. Other large-scale threats include forest conversion for oil palm, recurrent forest fires, drainage of peat swamp forests, illegal logging, mining, hunting, and to some extent, illegal wildlife trade. This species is not protected by law in Indonesia.

South Kalimantan, Indonesia. With no confirmed record from South Kalimantan, the model could not meaningfully infer the area's habitat suitability, although the Meratus mountains are predicted to be moderately suitable. South Kalimantan has a more pronounced dry season than the rest of Borneo, with resultant climatic conditions very different (extracted from Hijmans et al., 2005, 2015). Whether the prediction of low suitability reflects a true absence of this species or just the limited search effort so far could only be resolved by more surveys in South Kalimantan.

Central Kalimantan, Indonesia. A large part of Central Kalimantan is predicted to be suitable where interior lowland and hill forests are found, including the Bukit Baka – Bukit Raya National Park, the adjacent timber concessions namely Seruyan–Katingan Forest Reserve and surroundings, Bukit Perai – Bukit Rongga Forest Reserve and the Schwaner Range.

West Kalimantan, Indonesia. West Kalimantan is partly predicted to be suitable where lowland forest occurs, mostly within the Betung Kerihun National Park complex, adjacent to the Batang Ai – Lanjak Entimau complex in Sarawak. Other suitable areas include the Bukit Perai – Bukit Rongga protected forests, contiguous with the Bukit Baka – Bukit Raya National Park.

North Kalimantan and East Kalimantan, Indonesia. Almost all interior North and East Kalimantan is predicted

to be suitable where lowland and hill dipterocarp forests predominate. The large Kayan Mentarang National Park – Malinau Basin complex, and the Pulong-Tau complex in Sarawak form an important large transboundary conservation area predicted to be suitable. The eastern tip of the Sangkulirang and Mangkalihat mountains, predominantly karst, is also predicted to be highly suitable. To our best knowledge, no concrete evidence suggests that yellow-throated marten uses limestone habitat in Borneo, so the model's outcome for this particular area needs corroboration.

THREATS AND CONSERVATION PRIORITIES

Overall across Borneo, yellow-throated marten is usually amongst the small carnivores least frequently camera-trapped. Yet in mainland South-east Asia, it is often of moderate or even high encounter frequency relative to other small carnivores (see above). If rigorous investigation showed a genuine difference between regions, it might indicate lower densities or higher arboreality in Borneo than in mainland South-east Asia. There is no direct evidence for higher arboreality: the only camera-trapping survey with an extensive arboreal component of which we know, Wahyudi & Stuebing (2013), photographed it only on the ground.

Habitat predicted to be suitable for yellow-throated marten remains widespread in Borneo, except in coastal areas which are dominated by mangrove and deforested habitats. The interior regions of lowland and upland forest (except montane forests) received a high suitability index value. Many of these areas have been opened for logging and where data are available, yellow-throated marten has been documented.

The effects of logging on yellow-throated marten in Borneo are not well understood. The species seems unlikely to tolerate young and/or monoculture plantations and environments with very high anthropogenic habitat disturbance, although it has been recorded in mosaics of logged areas, tree plantations and secondary forest (Belden et al., 2007; Samejima et al., 2012). The long-term maintenance of a wide distribution and high occupancy of the island is likely to depend on how existing forests (including plantations and logging concessions) are managed and harvested. The model predicts areas that are suitable include the protected areas, forest mosaics of old tree plantations and secondary forests and most of the lowland forest of Borneo, including several large international transboundary areas. There have been no known records, to our knowledge, of yellow-throated marten in Borneo entering gardens or being persecuted by local people. Although these aspects have not been specifically investigated and might occur to some extent, the paucity, at most, of their occurrence might indicate that this species does not use mixed crop areas much or go near human populated areas. As of now, the species needs no obvious particular conservation intervention beyond the maintenance of extensive native forest. Understanding if, and under what circumstances, commercial plantations and conventional logging regimes can support the species would help refine predictions.

Survey priorities among natural habitats are high-elevation forests (over 1200 m a.s.l.; lower and upper montane forest) and limestone landscapes. The habitat reclassification scores, based on the 12 respondents' opinions showed large variation for high-elevation forests (Table 2). The highest known Bornean record is from Gunung Kinabalu at 1700 m a.s.l. (Payne et al., 1985) but this species reaches 4510 m a.s.l. in the Himalayas (Appel & Khatiwada, 2014) and 2600 m a.s.l. in Java (Corbet & Hill, 1992). These are different subspecies, so it might be premature to assume that upper montane forests hold this species in Borneo.

There has been no recent taxonomic investigation of this species. With investigations of some other small carnivores indicating that Bornean populations are more distinct than had previously been recognised (e.g., Veron et al., 2015a, b), it remains possible that the subspecies in Borneo, *M. f. saba* Chasen & Kloss, is an unrecognised cryptic species. Schreiber et al. (1989) considered the subspecies *M. f. chrysospila* Swinhoe, of Taiwan and *M. f. robinsoni* (Pocock), of Java morphologically quite distinct, and that "the yellow-throated marten ... is genetically differentiated in its vast geographic and ecological range, at least in terms of allele frequency in polymorphic genetic loci". The Bornean population might be of higher global conservation significance than is typically assumed, and its taxonomy warrants investigation.

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