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Predicted distribution of the Malay civet *Viverra tangalunga* (Mammalia: Carnivora: Viverridae) on Borneo

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

Abstract. The Malay civet *Viverra tangalunga* is a small carnivore occurring on several Indonesian islands, Malaysia, the Philippines and Singapore. The Malay civet occurs in diverse habitats, including primary and logged forest, and disturbed habitats near villages. It is listed by The IUCN Red List of Threatened Species as globally Least Concern; however, the extent to which it can tolerate habitat alteration is unclear. We analysed 69 (Balanced Model) and 115 (Spatial Filtering Model) location records to predict habitat suitability on Borneo. The resulting models predicted a high proportion of Borneo as suitable habitat for the Malay civet, although most coastal areas, swamp forests and high-elevation areas were predicted to be unsuitable. Highly suitable areas for the Malay civet include the central forest block in Sabah, much of the production forest in Sarawak and East and North Kalimantan, Bukit Baka Bukit Raya National Park, and production forest in Central Kalimantan. The Malay civet is currently widespread and appears somewhat tolerant of habitat alteration, and therefore there are currently no species-specific conservation requirements, beyond the maintenance of the current remaining habitat in protected areas.

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

Abstrak (Bahasa Indonesia). Tenggalung Malaya *Viverra tangalunga* adalah karnivora kecil yang berasal dari beberapa pulau di Indonesia, Malaysia, Filipina dan Singapura. Tenggalung Malaya dapat hidup di berbagai habitat, seperti hutan primer, hutan bekas tebangan, dan juga di habitat terganggu dekat dengan pemukiman. Jenis ini terdaftar dalam Daftar Jenis Terancam Punah IUCN kategori berisiko rendah; namun sejauh mana jenis ini dapat mentolerir perubahan habitatnya masih belum jelas. Kami menganalisis 69 (Model Penyeimbang) dan 115 (Model Spasial Tersaring) catatan jenis ini untuk memprediksi kesesuaian habitatnya di Borneo. Hasil analisis pemodelan memprediksi sebagian besar kawasan di Borneo sesuai sebagai habitat Tanggalung Malaya, meskipun sebagian besar wilayah pesisir, hutan rawa dan daerah yang memiliki elevasi tinggi diprediksi tidak sesuai sebagai habitatnya. Daerah yang diprediksi paling sesuai adalah kawasan hutan di bagian tengah Sabah, sebagian besar hutan produksi di Sarawak, Kalimantan Timur dan Kalimantan Utara, Taman Nasional Bukit Baka Bukit Raya dan juga hutan produksi di Kalimantan Tengah. Tanggalung Malaya saat ini diketahui tersebar luas dan sangat toleran, terhadap perubahan habitat oleh karena itu tidak diperlukan persyaratan konservasi spesifik, selain terus mempertahankan habitat yang tersisa dalam wilayah kawasan lindung.

Abstrak (Bahasa Malaysia). Musang Tanggalong *Viverra tangalunga* adalah spesis karnivora asal berbadan kecil yang dijumpai di beberapa kepulauan Indonesia, Malaysia, Filipina dan Singapura. Ia dijumpai di beberapa jenis habitat, termasuk hutan primer dan hutan yang telah dibalak, dan juga habitat termusnah berdekatan kampung. Ia disenaraikan sebagai Kurang Bimbang (Least Concern) dalam Senarai Data Merah Spesis Terancam IUCN; akan tetapi setakat mana ia tolerans terhadap habitat terubah masih tidak diketahui. Kami menganalisakan 69 (Model Seimbang) dan 115 (Model yang ditapis secara spasial) rekod kedudukan spesis untuk meramalkan kesesuaian habitat di Borneo. Model yang dihasilkan meramalkan kebanyakan kawasan Borneo sebagai sesuai untuk Musang Tenggalung, walaupun kebanyakan kawasan persisiran laut, hutan bencah dan kawasan tanah tinggi diramalkan tidak sesuai. Kawasan yang amat sesuai untuk Musang Tanggalong termasuk blok hutan di pertengahan Sabah, kebanyakan hutan produksi di Sarawak, Kalimantan Timur and Utara, Taman Negara Bukit Baka Bukit Raya dan juga hutan produksi di pertengahan Kalimantan. Musang Tanggalong kini dijumpai dengan meluas dan bersifat tolerans sedikit-sebanyak terhadap habitat terubah. Oleh itu, pada masa kini, permuliharaan spesis yang khusus tidak diperlukan melainkan penjagaan rangkaian kawasan terlindung dan habitat yang masih tinggal.

INTRODUCTION

The Malay civet *Viverra tangalunga* Gray, is a distinctively patterned small carnivore (Fig. 1) weighing 3–7 kg (Jennings & Veron, 2009) found on Singapore (Corbet & Hill, 1992; Lim & Ou Yang, 2012) Sumatra, peninsular Malaysia, the Philippines, and Borneo. In addition to its native range, there are introduced populations on several islands in South-east Asia (Corbet & Hill, 1992). Jennings et al. (2010) reported that Malay civets from peninsular Malaysia are significantly larger (6.6 kg and 5.8 kg for males and females, respectively) than those on Borneo (3.8 kg and 3.6 kg for males and females, respectively). The Malay civet is omnivorous and the diet includes small rodents, bats, birds, fruit and insects (Davis, 1962; Macdonald & Wise, 1979; Colón, 1999; Joscelyne, 2014). Activity is predominantly nocturnal (Colón, 2002; Jennings et al., 2006; Bernard et al., 2013; Ross et al., in press) or crepuscular (Azlan, 2005), although the latter was derived from only 19 records. This civet is predominantly ground-dwelling (Davis, 1962) but one radio-tagged individual was found to shelter in trees during rainstorms (Macdonald & Wise, 1979). A study in Sabah, Malaysian Borneo, found the mean home range size of 12 radio-collared animals to be 1.1 km^2 (Colón, 2002). Jennings et al. (2006) reported a mean home range size of 0.7 km^2, calculated from 10 radio-collared animals on Sulawesi; in peninsular Malaysia, Jennings et al. (2010) found the average range of seven animals to be 1.43 km^2. Colón (2002) found home ranges to be larger in logged forest than in primary forest, suggesting that densities may be lower in more disturbed habitat. This is also suggested by the lower encounter rates in logged forest reported by an earlier study of the same forest (Heydon & Bulloh, 1996). Throughout its range the Malay civet occurs in a variety of habitats including primary and logged forest, agricultural land, and near villages (Colón, 2002; Jennings et al., 2006; Jennings & Veron, 2011). On Borneo it occurs from sea level to at least 1452 m a.s.l. (AJ Hearn, J Ross & DW Macdonald, unpublished data). The Malay civet is tolerant of habitat change, at least to some degree (Colón, 2002), and will enter oil palm plantations (Borneo: Bernard et al., 2014; Ross et al., in press; Yue et al., 2015; Sumatra, Indonesia: Jennings et al., 2015; peninsular Malaysia: Jennings et al., 2010), although its reliance in such areas on forest near the plantations is currently unknown.

Because of a wide geographical range, apparent viability in modified habitats and a presumed large population size across its range, it is listed by The IUCN Red List of Threatened Species as globally Least Concern (Azlan et al., 2008). However, the extent to which the Malay civet can tolerate habitat alteration and its level of forest dependency remains unclear. While not specifically targeted by hunters on Borneo, it is eaten in some areas (Murphy, 2007) and, being predominantly ground-dwelling, snares may also be a threat. In locations near villages, this species may be persecuted as a perceived threat to poultry; both snaring and retribution killing are probably not intense enough to warrant conservation concerns for this species, but they might affect local abundance. The Malay civet is not listed within the CITES database, but is afforded legal protection in some of its range countries. In the Malaysian states of Sabah and Sarawak, it is protected under the Wildlife Conservation Enactment 1997 and the Wildlife Protection Ordinance 1998, respectively. It is not legally protected in Brunei or in Indonesia.

Fig. 1. A Malay civet *Viverra tangalunga* camera-trapped in Ulu Segama Forest Reserve, Sabah, Malaysia, on 16 July 2007 (Photograph by: Joanna Ross and Andrew Hearn).

RESULTS

Species occurrence records. Of 504 location records for the Malay civet, 302 were from the period 2001–2011. Almost half the records (251) had a precision of 0.5 km, but 110 records were inexact (precision over 5 km; Categories four and five), and excluded from the model (Table 1, Fig. 2) (see Kramer-Schadt et al. (2016) for methods). Records came from locations across most of Borneo with a high concentration from Sabah but none from South Kalimantan, where survey effort has been very low. Because of the bias of locations, we reduced the number of records to 69 (Balanced Model M_1) or 115 (Spatial Filtering Model M_2) for the modelling process.

Habitat associations. The land-cover scoring of the 16 respondents from the questionnaire survey showed a general belief that most categories were suitable to some extent (Table 2). There were, however, discrepancies amongst respondents for some categories such as swamp forest and mangrove, for which the reclassification ranged from zero (unsuitable) to four (very good habitat). The least suitable habitats were thought to be bare and burnt areas, mixed crops and water, and the most suitable all forest categories, except upper montane and mangrove. This variation in scores indicates unfamiliarity of the respondents with this relatively common species and suggests that some habitats such as swamp forest are generally underrepresented in surveys.

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Table 1. Summary of the occurrence records for the Malay civet *Viverra tangalunga* 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	251	39	60	248
Category 2 500 m – 2 km	37	5	12	23
Category 3 2–5 km	106	25	43	20
Category 4 above 5 km	72	–	–	4
Category 5 (no coordinates*)	38	–	–	7
Total	**504**	**69**	**115**	**302**

M_1 = Balanced Model; M_2 = Spatial Filtering Model (10 km); *only coarse location description was available.

Table 2. Land-cover reclassification for the Malay civet *Viverra tangalunga* based on the questionnaire results of 16 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.75	3–4
Upland forest	3.21	2–4
Lower montane forest	3.31	1–4
Upper montane forest	1.62	0–4
Forest mosaics/lowland forest	3.21	*
Forest mosaics/upland forest	2.97	#
Swamp forest	2.14	0–4
Mangrove	1.23	0–4
Old plantations	2.75	1–4
Young plantations and crops	1.77	1–3
Burnt forest area	0.85	0–4
Mixed crops	1.31	0–4
Bare area	0.07	0–1
Water and fishponds	0.14	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 suitability index (HSI) model. We predicted that a large proportion of Borneo is suitable habitat for the Malay civet. The least suitable areas were predicted to be the coastal areas and the peat swamp forests in Central Kalimantan. Few records came from these habitats, but this might stem from survey bias rather than a true lower abundance. South Kalimantan was also predicted to be unsuitable, as were high elevation areas in the interior of the island. The mapped predictions of the habitat suitability index model in Fig. 3 therefore need to be interpreted with caution (see Kramer-Schadt et al. (2016) for more details). Although search-effort bias has been minimised during the modelling, location record deficient areas such as South Kalimantan 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, further surveys could determine whether 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). The northern range of the Malay civet does not extend to those parts of South-east Asia with a strong dry season and it is

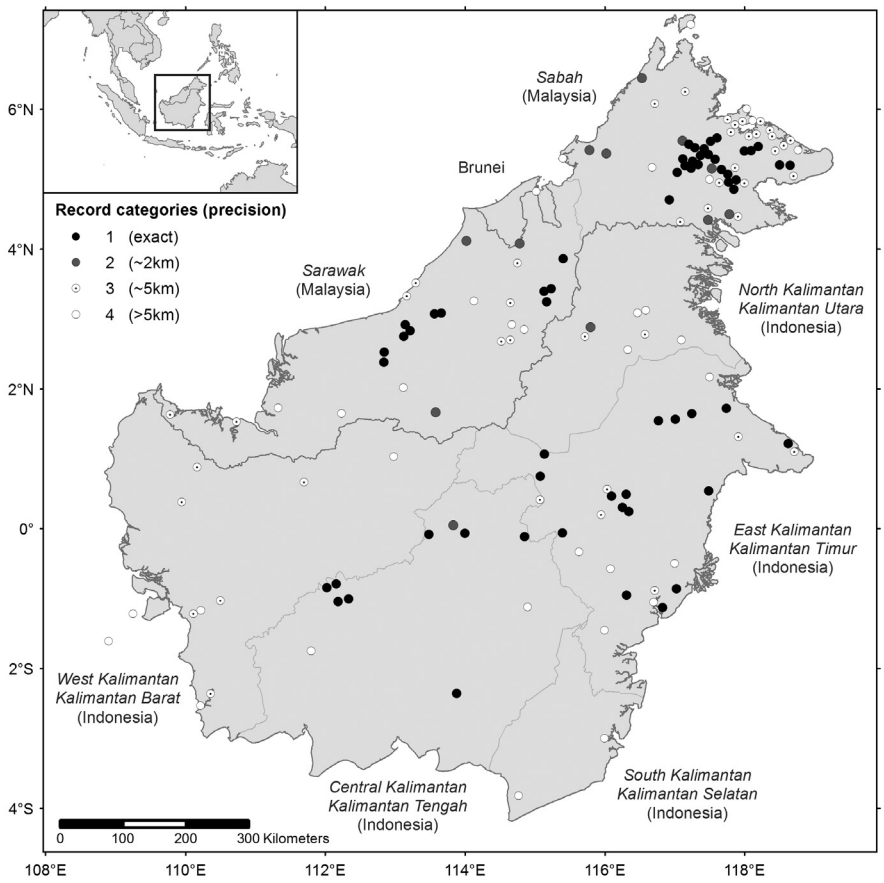

Fig. 2. Location of Malay civet *Viverra tangalunga* occurrence records across Borneo, showing categories of spatial precision as well as country and state boundaries.

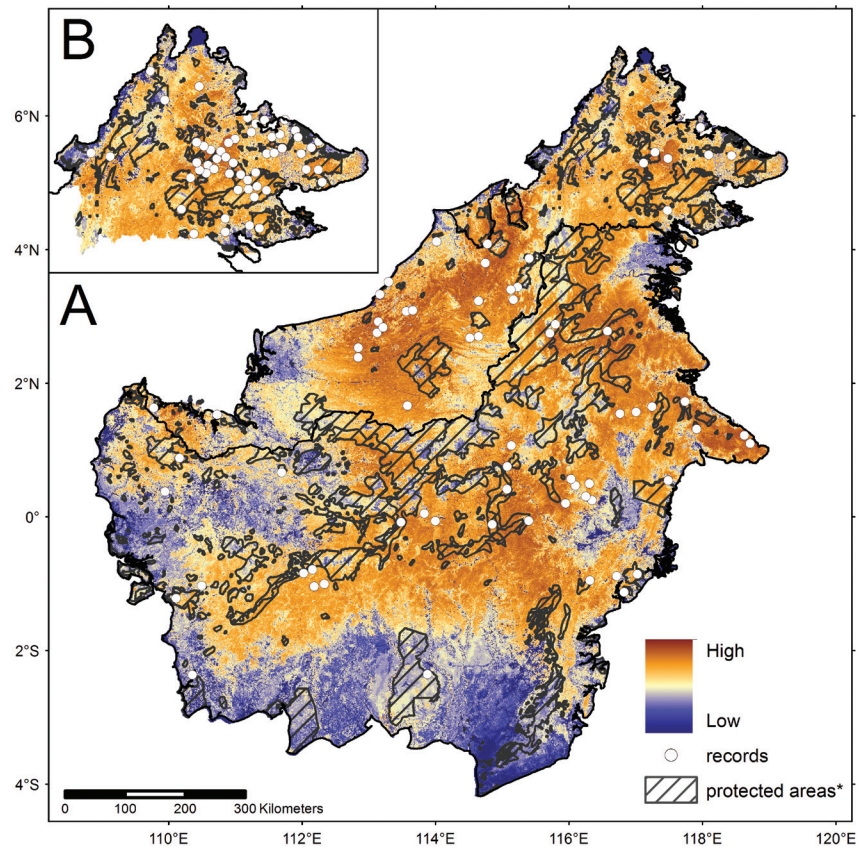

Fig. 3. Predictive Habitat Suitability Index (HSI) models for the Malay civet *Viverra tangalunga*, including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al. (2016).

plausible therefore that its distribution might be localised in South Kalimantan. The remaining areas of Borneo and in particular Sabah and a large part of Sarawak were predicted to be highly suitable.

DISCUSSION

Habitat suitability. The Malay civet is a relatively common and widespread carnivore both on Borneo and further throughout its range (Payne et al., 1998; Jennings & Veron, 2011), and this is reflected by this study obtaining for this species both more records and more locations than for any other Bornean small carnivore (Kramer-Schadt et al., 2016: Tables 2–3). Nevertheless, the precise habitat requirements of the Malay civet remain little known and our modelling provides testable predictions. The habitat associations based on the scoring of respondents was limited in that they were based on individual's knowledge and speculation rather than quantitative data. This is reflected in the large range of values for some land-cover classes, and increased the uncertainty in the final model. The distribution of occurrence records (Figs. 2, 3) shows a similar pattern, suggesting an association with lowland forest and avoidance of anthropogenic habitats such as plantations and mixed crops. Both these methods, however, are limited by search-effort bias; surveys have been focused in areas of high conservation concern, usually forest areas at risk of conversion or with moderate disturbance. Less attention has been given to highly degraded or converted areas or areas where the risk is lower. This means that most surveys have been conducted in lowland forest and fewer at high elevations, in swamp forest or in agricultural areas. Employing a similar analysis, Jennings & Veron (2011) also found more records for lowland, rather than high-elevation forests; however, differential survey effort was not accounted for in this study. To what extent the prediction of low suitability of high elevations on Borneo stems from misleadingly few records in those areas is unclear. A survey of Crocker Range Park (conducted too late for inclusion in these models) recorded Malay civets at 78% of camera stations where the mean elevation was 1032 m a.s.l., including the highest survey point of 1452 m a.s.l. (AJ Hearn, J Ross & DW Macdonald, unpublished data). The Malay civet has also been recorded at 1400 m in the Ulu Padas region of southern Sabah and at 1300 m in the Hose mountains, Sarawak (JF Brodie, unpublished data). However, this might be a relatively localised association reflecting the presence of certain habitats. Our results suggest that large areas of Borneo are suitable habitat for the Malay civet. This is to be expected given the apparent habitat plasticity of this species (e.g., Colón, 2002; Jennings et al., 2006; Jennings & Veron, 2011). Identifying priority areas for such a common and widespread species would have little value. However, we have identified areas that the models predicted to be particularly suitable.

Sabah, Malaysia. The majority of Sabah was predicted to be suitable habitat for the Malay civet; the coastal areas are the exception to this pattern. In 2010 forest cover in Sabah was roughly 51% of total land area (Reynolds et al., 2011) and while most of these forests are commercial forest reserves, there is some degree of protection in these areas. These extensive production forests were predicted to be suitable habitat. Eastern Sabah was predicted to be less suitable, probably because of the extensive oil palm plantations in the area.

Sarawak, Malaysia. Sarawak has a similar pattern to Sabah, in that most of the area was predicted to be suitable habitat. The exception was the far south-west portion of Sarawak which was predicted to be unsuitable; possibly an artefact of there being only a few records from this area. Very few records were from protected areas in Sarawak. For a widespread species it is possible that this reflects the pattern of survey distribution rather than an indication that protected areas in Sarawak do not support the species.

Brunei Darussalam. A high proportion of Brunei was predicted to be suitable habitat for the Malay civet. We did not trace any spatially precise records from the country, but there was one record from the transboundary forest complex of Mulu National Park (Sarawak) and Labi Hills Forest Reserve (Brunei). Labi Hills was predicted by the model to be suitable habitat and, given that it is contiguous with Mulu NP, it is likely that the Malay civet is present in Brunei, and that the absence of records is merely a reflection of low survey here.

East Kalimantan and North Kalimantan, Indonesia. Large areas of East and North Kalimantan were predicted to be suitable habitat for the Malay civet. Much of this area, however, falls outside national parks and other protected areas. Areas of predicted low suitability are the northwest portion of North Kalimantan and the Sungai [=River] Mahakam region in East Kalimantan.

South Kalimantan, Indonesia. Most of South Kalimantan was predicted to be poor habitat for the Malay civet, especially low-lying areas in the far south. Unlike the other areas of Borneo however, even the more rugged terrain of the Meratus mountains was predicted to be unsuitable. South Kalimantan is more seasonal than the rest of Borneo, with a pronounced dry season. This may render the state unsuitable for the Malay civet as the northern limit of its known world range does not reach areas where the climate is dry enough for a vegetation shift from evergreen to semi-evergreen forest.

Central Kalimantan, Indonesia. Our predictive models suggest that the extensive peat swamp forests in the south are poor habitat for the Malay civet, although there are recent camera-trap records from the predominantly peat swamp forest of Sabangau National Park (Cheyne et al., 2010). This prediction might be a spurious outcome from respondents' ranking swamp forest as low in suitability (Table 2). Areas further inland, such as around Bukit Baka Bukit Raya National Park, are predicted to be more suitable. The areas of highest suitability, however, have no formal protection and there are several records from these areas.

West Kalimantan, Indonesia. The majority of West Kalimantan was predicted by our models to be of low

suitability for the Malay civet and we obtained few records from this province. This paucity of records is possibly because of a low survey effort. The areas of highest predicted suitability are in the east of the province; this area might have been predicted to be suitable because of records close by in neighbouring Central and East Kalimantan and the similarity of the habitat between these areas.

General priorities. The Malay civet is not a species of immediate conservation concern and is one of the better studied Bornean carnivores (see Colón, 1999, 2002). It does not appear to be restricted to any specific habitat; nevertheless, like many Bornean mammals, it suffers from a continuing loss of natural habitat, although currently not at rates sufficient to trigger concern. We recommend that future research emphasise better understanding the extent to which the Malay civet can use oil palm and other plantations, determining whether viable and self-sustaining populations are supported by these plantations, and the effect that the use of rodenticides might have on this species. Determining the species's use of high elevation areas is also warranted.

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