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Predicted distribution of the Malay weasel *Mustela nudipes* (Mammalia: Carnivora: Mustelidae) on Borneo

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

Abstract. Malay weasel *Mustela nudipes* is restricted to the Sundaic sub-region, in Borneo, Sumatra and the Malay–Thai peninsula. A distribution model suggested that the species is widespread on Borneo and occurs in a wide range of habitats. The ecology of the species is poorly known, making it difficult to predict how its populations are likely to be affected by ongoing deforestation and forest degradation. A summary of likely key habitats and priority actions for this species on Borneo is provided.

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

Abstrak (Bahasa Indonesia). Musang Kepala-Putih *Mustela nudipes* persebarannya terbatas pada sub-wilayah Sunda, di Pulau Borneo, Sumatera dan Semenanjung Malaysia–Thailand. Suatu model persebaran dari Musang Kepala-Putih menunjukkan bahwa jenis ini tersebar luas di Borneo dan dapat dijumpai di berbagai tipe habitat. Namun ekologi dari jenis ini masih belum sepenuhnya diketahui, sehingga sulit memperkirakan bagaimana populasi *M. nudipes* akan terpengaruh oleh adanya penggundulan dan penurunan kualitas hutan. Suatu rangkuman mengenai habitat kunci dan langkah-langkah prioritas untuk jenis ini telah disajikan.

Abstrak (Bahasa Malaysia). Pulasan Tanah *Mustela nudipes* terhad kepada kawasan Sunda, di Borneo, Sumatra dan Semenanjung Malaya–Thailand. Suatu model taburan bagi *Mustela nudipes* mencadangkan bahawa spesis ini tersebar meluas di Borneo dan berada di pelbagai jenis habitat. Ekologi spesies ini tidak banyak diketahui dan ini menyulitkan proses peramalan bagaimana populasi *M. nudipes* mungkin akan dipengaruhi oleh kemusnahan hutan serta degradasi kualiti hutan. Kami mencadangkan beberapa habitat dan tindakan yang terpenting untuk memastikan pemuliharaan spesis ini.

INTRODUCTION

Duckworth et al. (2006) discussed the taxonomy, global distribution and natural history of the Malay weasel *Mustela nudipes* Desmarest, in detail and here we reiterate the main findings only. *Mustela nudipes* (Fig. 1) is one of five species of *Mustela* Linnaeus, found in South-east Asia out of a world total of about 17 species in the genus. *Mustela nudipes* is restricted to the Sundaic sub-region, which includes Borneo, Sumatra and the Malay–Thai peninsula (Chasen, 1940; Lekagul & McNeely, 1977). Reports of its existence on Java are unproven. It is a strikingly coloured species, with a bright orange body and a white head; confusion with other species is unlikely (but see Ross et al., 2012). Its pelage varies in colour but, despite earlier speculation (Chasen & Kloss, 1931), this shows no geographic basis and the species is monotypic (Brongersma & Junge, 1942). Little is known about the species's ecology (Payne et al., 1985; Ross et al., 2013). Reviews of small carnivores on small islands covering the species's range (Meijaard, 2003; Meiri et al., 2004) traced no records, suggesting that fairly large areas are needed to retain populations. Habitat use and altitudinal range are discussed below.

Globally, *M. nudipes* is listed as Least Concern on The IUCN Red List of Threatened Species (Duckworth & Kanchanasaka, 2008). Regarding its conservation status on Borneo, the species is nowhere listed as a fully protected species. Under the Sabah Wildlife Enactment 1997, it is considered a protected species in the Malaysian state of Sabah, which means that it can be hunted and collected with an appropriate license. The species is not protected under the Sarawak Wild Life Protection Ordinance 1998, nor in

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Table 1. Summary of the occurrence records for Malay weasel *Mustela nudipes* 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	27	15	22	22
Category 2 500 m – 2 km	11	4	11	3
Category 3 2–5 km	60	37	51	16
Category 4 above 5 km	16	–	–	5
Category 5 (no coordinates*)	15	–	–	0
Total	**129**	**56**	**84**	**46**

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

Fig. 1. Malay weasel *Mustela nudipes* camera-trapped in Crocker Range Park, Sabah, Malaysia at 885 m a.s.l. on 4 November 2011. Credit: A.J. Hearn / WildCRU.

Indonesia or Brunei Darussalam, suggesting that it can be hunted and caught in these areas.

RESULTS AND DISCUSSION

Species occurrence records. In total, 126 occurrence records for *M. nudipes* were collected from across Borneo, including a significant number of recent records (2001–2011) (Fig. 2; Table 1). The analysis excluded 35 records of low precision (over 5 km; Categories 4 and 5), using 56 records (Balanced Model) and 84 records (Spatial Filtering Model) for the modelling exercise (see Kramer-Schadt et al. (2016) for details on the modelling). Most records were obtained from Sabah and Sarawak, but the species was also recorded in Brunei Darussalam and all five provinces of Kalimantan (Fig. 2). The analysis was consistent with the suggestion of Duckworth et al. (2006) that the species might be absent from south-eastern Borneo, which has a pronounced dry season (a possible reason why the species is missing from other areas in its potential range with long dry seasons). However, some other large parts of Borneo lacked records, including most of the province of West Kalimantan; therefore, given the generally low survey effort in the southern half of Borneo, historical and recent, it is possible also that the species lives in south-eastern Borneo but has yet to be documented.

Habitat associations. Eight respondents provided input into the assessment of land-cover class suitability for *M. nudipes* (Table 2). Lowland forest, upland forest, lower montane forest, upper montane forest, forest mosaics / lowland forest, forest mosaics / upland forest, swamp forest and old plantations were considered the most suitable land-cover types for the species. This suggests that the species uses a wide range of vegetation types and could also occur in degraded and secondary forests and scrublands. As discussed by Duckworth et al. (2006), however, the species does not appear to be commonly seen anywhere.

Habitat suitability index (HSI) model. The distribution modelling suggests that *M. nudipes* still occurs over large parts of Borneo, including some of the higher-altitude areas which are less threatened by deforestation than the lowland areas (Fig. 3). With ongoing development of lowland forests into landscapes dominated by small- and large-scale agriculture and silviculture, most populations of *M. nudipes* on Borneo are likely to end up living in fragmented, multifunctional landscapes. Two records from near Balikpapan in a mix of farmland, alang-alang *Imperata cylindrica* Linn. grassland, and patches of secondary forest and acacia indicate an ability to use non-forest vegetation types, as do records from suburbs (Duckworth et al., 2006). At present, however, not enough is known about the long-term ability of the species to persist in non-forest habitats. Furthermore, it would be valuable to clarify the ability of *M. nudipes* to cross open areas and roads, which has been occasionally documented but appears to occur infrequently (Duckworth et al., 2006). Similarly, it is not known to what extent the many rivers and streams form barriers to dispersal of *M. nudipes*. Like other species of *Mustela* that are known to swim well (King & Powell, 2007; Veale, 2012), *M. nudipes* seems to be comfortable in water. Brongersma & Junge

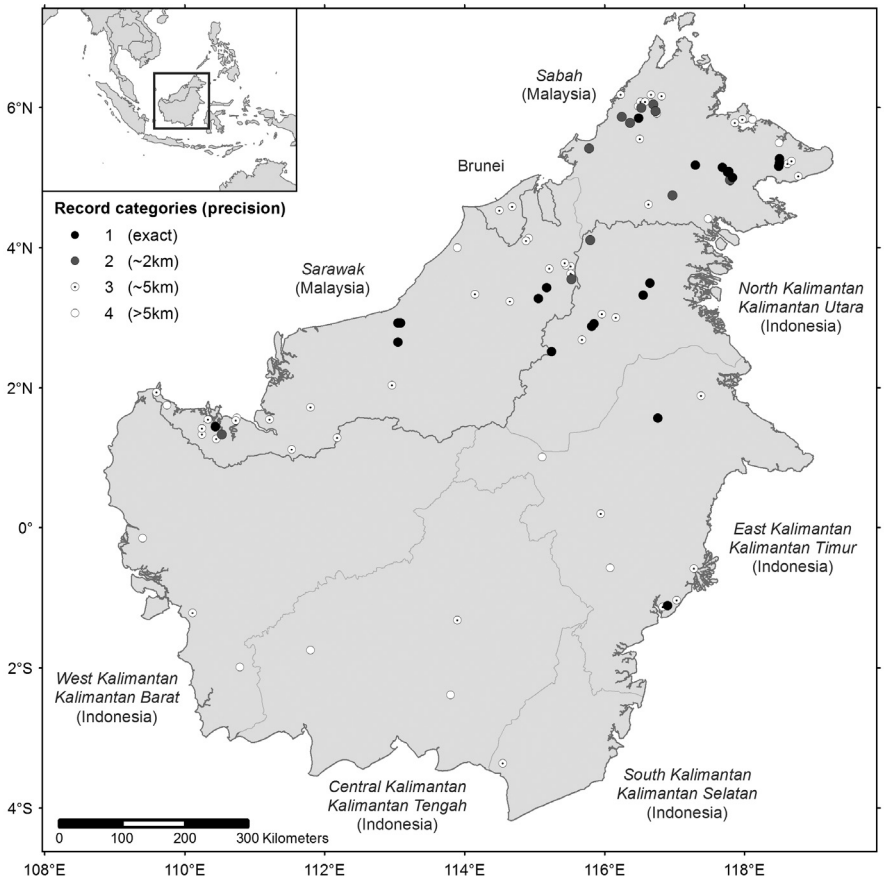

Fig. 2. Location of Malay weasel *Mustela nudipes* occurrence records on Borneo, with categories of spatial precision as well as countries and state boundaries.

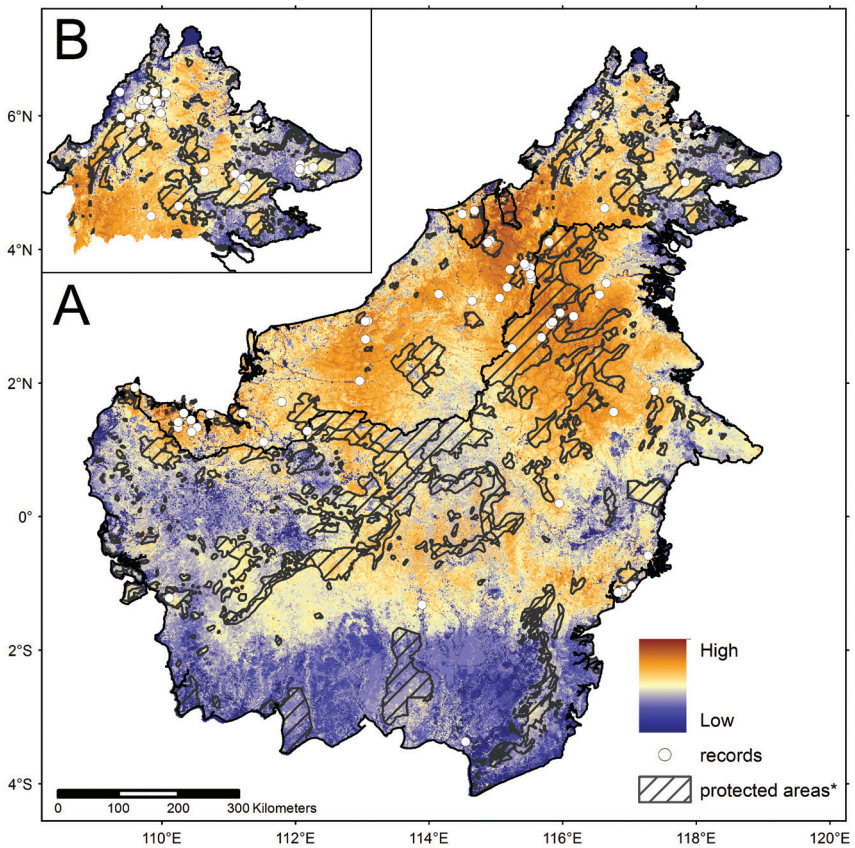

Fig. 3. Predictive Habitat Suitability Index (HSI) models for Malay weasel *Mustela nudipes* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al. (2016).

Table 2. Land-cover reclassification for Malay weasel *Mustela nudipes* based on the questionnaire results of eight respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.50	3–4
Upland forest	3.33	3–4
Lower montane forest	2.67	1–4
Upper montane forest	1.83	0–4
Forest mosaics/lowland forest	2.65	*
Forest mosaics/upland forest	2.58	#
Swamp forest	2.00	0–4
Mangrove	1.00	0–3
Old plantations	2.00	0–3
Young plantations and crops	1.38	0–3
Burnt forest area	0.75	0–2
Mixed crops	1.13	0–2
Bare area	0.13	0–1
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).

(1942) even speculated that it might be semi-aquatic, based on one seen beside a stream and another slain with a paddle as it swam across the Bruny tributary of the upper Sungai [= River] Mahakam. It is likely that rivers, especially smaller ones, are not much of a barrier for *M. nudipes*.

Concluding remarks and conservation priorities. The future of many forest-dependent species on Borneo will be determined by the extent to which forests can be maintained. There are basically two land use choices for permanent maintenance of natural forests. They are either protected (in national parks, nature reserves, catchment protection forests etc.) or they are used for selective timber extraction with reduced impact logging techniques ensuring that such extraction can be maintained permanently (Meijaard et al., 2012). Research suggests that in Indonesian Borneo the two land types are equally effective in maintaining overall forest cover, if properly corrected for landscape context (e.g., any forests at high altitude would be less likely to be cut down because of restricted access) (Wich et al., 2012; Gaveau et al., 2013). Protected areas are more effective than timber concessions in maintaining areas of intact forest (Santika et al., 2015), which is important for the conservation of species that depend on undisturbed forests. Financially, on the other hand, natural forest timber concessions provide a more cost-effective solution to protecting large areas of forests (KA Wilson et al., 2010, H Wilson et al., 2014). What this means for *M. nudipes* remains unclear because the effects of timber harvest and related disturbances upon it are insufficiently studied.

If natural forests on Borneo are not maintained, the lands are generally converted to monoculture plantations such as oil palm, acacia, rubber or eucalyptus. Little is known about the status of *M. nudipes* in such plantation landscapes (Duckworth et al., 2006), but it has been recorded up to 1.5 km from the nearest native forest within oil palm plantations (Ross et al., 2013). High densities of rodents in oil palm plantations (Meijaard & Sheil, 2013) might attract a carnivorous species such as *M. nudipes*. Understanding use of oil palm and other plantations by *M. nudipes* is therefore another important area for research.

A final issue that warrants study is the extent to which *M. nudipes* is affected by hunting or collecting for other purposes. Duckworth et al. (2006) mentioned various uses of the species, but little is known about whether it is targeted by hunters and trappers and whether it is affected by the widespread indiscriminate use of snares on Borneo. Snares mostly target species such as sambar *Rusa unicolor* Kerr, or bearded pig *Sus barbatus* Müller, but smaller snares set for porcupines, civets and ground birds might also affect *M. nudipes*. Further, interview-based hunting surveys, when properly designed and implemented (Mohd-Azlan et al., 2013), could helpfully determine catch frequencies for *M. nudipes*, especially because of its distinct morphological characteristics which makes it hard to confuse with other species.

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