

Predicted distribution of short-tailed mongoose *Herpestes brachyurus* (Mammalia: Carnivora: Herpestidae) on Borneo

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

Abstract. Short-tailed mongoose *Herpestes brachyurus* is known to inhabit Borneo, Sumatra and peninsular Malaysia. Locality records show that it is widespread and probably common in at least the northern half of Borneo. Records are much sparser south of 2°N. It occurs in forest and, to a poorly clarified extent, non-forest habitats. Eighty-six spatially precise records were used to model its Bornean distribution. This modelling is complicated by several factors: difficulties of field separation from collared mongoose *H. semitorquatus* (reducing the number of available records); limited interest in, and thus familiarity with, the species (perhaps reducing the reliability of the respondents' opinions on habitat use); and strong evidence that altitudinal range and perhaps other aspects of habitat use differ between major landmasses (also potentially confounding opinions on habitat use). Within Borneo it is important to (1) clarify the extent of the species' use of degraded and non-forest habitats, and (2) assess whether the paucity of records in Borneo from south of 2°N reflects a rarity of animals or simply low survey effort. Irrespective of short-tailed mongoose's precise habitat-use patterns in Borneo, it seems unlikely to be under major threat there. Its extent of occurrence encompasses all, or nearly all, the island; it has a large potential range outside the lowlands where large-scale forest clearance has been concentrated; there is no evidence of any association with any particularly threatened microhabitat; and it is highly unlikely to be subject to targeted or intensive hunting except locally as a livestock predator.

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

Abstrak (Bahasa Indonesia). Garangan Ekor-Pendek *Herpestes brachyurus* dapat dijumpai di wilayah Borneo, Sumatera dan Semenanjung Malaysia. Catatan setempat menunjukkan satwa ini tersebar luas, tampaknya sangat umum untuk sebagian wilayah utara Borneo. Catatan menunjukkan keberadaanya semakin jarang ke arah selatan pada 2°LU. Dijumpai di hutan, serta pada informasi terbatas, di habitat bukan hutan. Sebanyak 86 catatan perjumpaan digunakan dalam pemodelan persebaran di Borneo. Pemodelan ini cukup rumit karena beberapa hal: keterbatasan kemampuan membedakan dari Garangan Ekor-Panjang *H. semitorquatus* (menurunkan jumlah data akurat), rendahnya perhatian pada satwa ini, sehingga menurunkan pemahaman jenis (menurunkan kemampuan pemahaman responden terhadap habitat sesungguhnya) dan adanya bukti kuat bahwa ketinggian wilayah dan mungkin aspek lain dari penggunaan habitat berbeda untuk setiap bentang alam (menyebabkan adanya kesalahan tafsir dari perkiraan penggunaan habitat). Untuk wilayah Borneo, sangat penting untuk (1) memperjelas dalam hal penggunaan wilayah oleh satwa pada wilayah habitat terganggu dan bukan hutan dan (2) mengkaji apakah rendahnya catatan di Borneo pada wilayah selatan dari 2°LU karena jarangnya satwa ini atau karena rendahnya data survey. Terlepas dari tepatnya pendugaan penggunaan habitat oleh Garangan Ekor-Pendek di Borneo, tampaknya jenis ini tidak dalam tingkat terancam. Luasnya persebaran membuktikan hal: persebaran yang sangat luas hingga di luar kawasan dataran rendah dimana pembalakan hutan terpusat; tidak ada bukti nyata akan hubungan dengan ancaman mikroklimat dan tampaknya tidak pernah menjadi target buruan terkecuali diburu karena menganggu hewan ternak.

Abstrak (Bahasa Malaysia). Bambun Ekor Pendek *Herpestes brachyurus* diketahui berada di Borneo, Sumatra dan Semenanjung Malaysia. Rekod-rekod menunjukkan ia bertaburan luas dan mungkin biasa ditemui di sebelah utara Borneo. Rekod-rekod menjadi berkurangan di sebelah selatan 2°N. Ia dijumpai di hutan dan kurang jelas setakat mana ia menggunakan kawasan bukan hutan. Lapan puluh enam rekod tepat digunakan untuk meramalkan taburannya di Borneo. Proses pemodelan dirumitkan oleh beberapa faktor: kesukaran mengasingkan spesis ini dari Bambun Ekor Panjang *H. semitorquatus* (ini seterusnya mengurangkan jumlah rekod yang ada); minat dan kebiasaan yang terhad terhadap spesis ini (mungkin mengurangkan kebolehpercayaan pendapat para pakar tentang penggunaan habitat oleh spesis ini); dan cukup bukti yang menunjukkan julat penggunaan ketinggian atas paras laut dan mungkin ciri-ciri penggunaan habitat yang lain, biasanya tidak sama di antara wilayah-wilayah besar (ini juga mengakibatkan pertentangan pendapat tentang penggunaan habitat oleh spesis ini). Di dalam Borneo, ia penting untuk (1) menjelaskan tahap penggunaan habitat yang bukan hutan dan hutan yang sudah didegradasi oleh spesis ini, dan (2) menjelaskan sama ada kekurangan rekod dari sebelah selatan 2°N menunjukkan spesis ini memang jarang didapati di sana atau ia hanya kerana kurang usaha pemantauan dan kajian di sana. Tidak kira apa jenis

habitat yang digunakan oleh Bambun Ekor Pendek di Borneo, spesis ini tidak mungkin menghadapi ancaman yang serius di pulau ini. Taburannya merangkumi semua, atau hampir semua, pulau Borneo; jujat penggunaan habitatnya berpotensi merangkumi kawasan-kawasan di luar tanah rendah di mana kebanyakan aktiviti pembalakan dan penukaran hutan asal secara besar-besaran tertumpu; tiada bukti yang ianya ada kaitan dengan apa-apa jenis habitat yang terancam; dan tiada kemungkinan besar spesis ini menjadi sasaran pemburuan secara besar-besaran tetapi hanya mungkin diburu secara tempatan kerana memakan binatang ternakan.

INTRODUCTION

Mongooses (Herpestidae Bonaparte) occur widely in the Old-world tropics (Asia and Africa) and adjacent warm temperate areas; human introduction, particularly of one species, has expanded the family's range greatly. Three species occur in the Greater Sunda islands of Borneo, Java and Sumatra: collared mongoose *Herpestes semitorquatus* Gray, in Borneo and Sumatra; small Asian mongoose *H. javanicus* (É. Geoffroy St Hilaire), in Java and – perhaps only by introduction – Sumatra; and short-tailed mongoose *H. brachyurus* Gray, in Borneo and Sumatra (e.g., Corbet & Hill, 1992; Jennings & Veron, 2011; Holden & Meijaard, 2012; Ross et al., 2012). Outside the Greater Sunda islands, short-tailed mongoose has been recorded reliably only from peninsular Malaysia (e.g., Wells, 1989; Van Rompaey, 2000). It was generally accepted to inhabit Palawan and associated islands in the Philippines (part of the Sunda faunal province, rather than the Philippines faunal province; Heaney, 1986) but Wilson et al. (2006) considered the Philippine populations would be better treated as a distinct species, *H. parvus* Jentink, although they did not detail why. More recently, Veron et al. (2015) considered, under both genetic and morphological features, that these populations are closer to collared mongoose. Therefore, the Philippines are excluded here from short-tailed mongoose's range. Some authors (e.g., Gilchrist et al., 2009; Jennings & Veron, 2011) have accepted a short-tailed mongoose specimen (AMNH M-31597) as evidence of the species's occurrence in Thailand's far south. Whilst occurrence there is plausible, anomalies concerning the specimen's documentation prevent its being taken as proof of this (Chutipong et al., 2014).

Collared mongoose and brown mongoose *H. fuscus* Waterhouse, of southern India and Sri Lanka have each been considered conspecific with short-tailed mongoose, by, e.g., Schwarz (1947) and Wozencraft (1993) respectively. Although the specific statuses of these two are now universally accepted, taxonomic uncertainty remains with short-tailed mongoose. A single mongoose specimen from the Baram district, Sarawak, with a distinctive skull was named as Hose's mongoose *H. hosei* Jentink. No similar specimens have since been collected and this specimen is now



Fig. 1. Short-tailed mongoose *Herpestes brachyurus*, Paya Maga, Sarawak, at 1548 m a.s.l., close to the highest altitude at which the species has ever been recorded; 24 November 2014 (photograph by: WWF Malaysia).

generally considered to be an atypical short-tailed mongoose (e.g., Schreiber et al., 1989; Corbet & Hill, 1992; Veron et al., 2015). If it be a valid species, separation under field and camera-trap conditions from short-tailed mongoose would be extremely challenging (Payne et al., 1985). Even aside from the 'Hose's mongoose' conundrum, short-tailed mongoose might well comprise more than one species: Veron et al. (2015) found that Bornean short-tailed mongooses differed markedly in mitochondrial DNA from those of Sumatra and peninsular Malaysia. The limited nuclear DNA did not, however, consistently support the mitochondrial DNA results (present authors' re-analysis based on solely the nuclear DNA, without involving mitochondrial DNA; sequences obtained from Genbank). Therefore, further information is needed before concluding that two species are involved.

In common with most carnivores endemic to South-east Asia, short-tailed mongoose (Fig. 1) has been little studied in the field, and only outside Borneo (e.g., Jennings et al., 2010). Van Rompaey (2000) collated the sketchy information then available on the species. Subsequently, general faunal surveys and studies of other species have generated many more records on Borneo (e.g., Matsubayashi et al., 2007, 2011; Mathai et al., 2010; Wilting et al., 2010; Brodie & Giordano, 2011; Low, 2011; Ross et al., 2012, in press; Samejima & Semiadi, 2012; Wahyudi & Stuebing, 2013). The identification to species of mongoose field sightings and camera-trap photographs in Borneo, Sumatra and peninsular Malaysia requires care and is sometimes not undertaken, even by those highly experienced in the region: as examples, in Sabah, Ross et al. (2012) identified 321 camera-trapped

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mongoose records to species but left 61 (16% of the total) unidentified, whilst all 16 mongooses camera-trapped in Jerangau Forest Reserve, peninsular Malaysia, by Azlan (2003) and all those camera-trapped in eastern Sabah by Bernard et al. (2014) were left unidentified to species. Thus, some records published as short-tailed mongoose by less cautious observers may be in error; but many good records will have been lost among the ‘unidentified mongoose’ category.

The first field study of short-tailed mongoose comprised five animals radio-tracked in Krau Wildlife Reserve, peninsular Malaysia (Jennings et al., 2010). These five were concluded to be solitary and territorial; the mean home range size (95% minimum convex polygon) of the three males was 233 ha and of the two females was 132 ha (Jennings et al., 2010). But it is not totally solitary as an adult: camera-trap photographs from Borneo, at least in Sabah, sometimes show duos of adult-size animals (JR and AJH pers. obs.).

Short-tailed mongoose is active mostly by day (e.g., Cheyne et al., 2010; Jennings et al., 2010; Wilting et al., 2010; Ross et al. in press). In one area of Sarawak, it was twice detected active by night (e.g., Belden et al., 2007; G. Belden in litt., 2014). Camera-trapping proves that it spends much time on the ground, and past statements of habitual climbing (e.g., as cited in Van Rompaey, 2000), which would, if true, complicate the interpretation of camera-trap results, require corroboration to be accepted. JR and AJH (pers. obs.) have one camera-trap record of a wild animal climbing a tree to at least 1 m (the top of the frame of view).

Short-tailed mongoose is categorised as Least Concern on The IUCN Red List of Threatened Species (IUCN, 2015). It is obviously too numerous and widespread to trigger any range or population size criterion (see thresholds in IUCN, 2012). However, the application of decline-rate criteria is less clear. In peninsular Malaysia, it has been recorded only in the extreme lowlands (see below), where deforestation is concentrated (e.g., BirdLife International, 2001); across its range records come overwhelmingly from forest landscapes; and there appears to be no published critical assessment of its status in deforested areas and in degraded forest on any of the three landmasses it occupies. Its Red List categorisation is therefore presently under review.

It is protected under the Sarawak Wild Life Protection Ordinance 1998 and the Sabah Wildlife Enactment 1997 under Schedule 2 Part I whereby only limited hunting and collection are permitted, upon the issuance of license. It is not protected in Brunei or in Indonesia.

RESULTS AND DISCUSSION

Species occurrence records. In total, 261 records were collated; 52 were excluded from modelling because their spatial precision was too low (over 5 km; Categories 4 and 5, Fig. 2). Of the remaining records, 151 were collected within 2001–2011 (Table 1). Most records came from Sabah, but records were obtained from all Borneo’s political

units except South Kalimantan (see below). Because of geographic survey-effort bias, only 53 (Balanced Model = M_1) or 86 (Spatial Filtering Model = M_2) records were used for modelling (see Kramer-Schadt et al. (2016) for details).

Habitat associations. Short-tailed mongoose has received little attention from naturalists and zoologists (indeed, at least one prolific record provider to the Borneo Carnivore Symposium did not collate and send his records of this species, considering it insufficiently interesting to justify the time it would have taken). Unsurprisingly, the 13 questionnaire respondents showed wide variation in their habitat suitability scores for land-cover classes (Table 2), with one of the 13 assessed classes, swamp forest, being scored anywhere between 0 and 4 (the full range), and seven more between 0 and 3 or 1 and 4. The only consistent responses were for lowland forest (rated as highly suitable, and where most camera-trapping occurs, meaning most respondents would be best informed) and bare areas, water and fishponds, and water (rated as unsuitable). Similarly, the five habitats with respondents’ scores ranging from 0 to 3 are mostly those that have lacked extensive mammal survey or research, and this is less true for the two with scores of 1–4 (upper and lower montane forest). The broad range of opinion for swamp forest is surprising given that in lowland mixed peat swamp-forest at Sabangau, Central Kalimantan, short-tailed mongoose is among the most commonly camera-trapped small carnivores (Cheyne et al., 2010). The uneven consensus on habitat reclassifications may have resulted in the averaged picture, used in the model, not faithfully representing this animal’s habitat use in Borneo.

Although in Borneo this mongoose has been stated to be a habitat generalist, the evidence for this comes mostly from broad-brush remarks. Such include “both mongooses [the other being collared mongoose] adapt to man-made habitats” (Davies & Payne, 1982: 153) and “occurs in tall and secondary forests. Sometime enters plantations and gardens” (Payne et al., 1985: 287). They are based on an unknown number of original records.

There is perhaps only one semi-detailed, demonstrably original, remark about use of non-forest areas: “seems to be relatively common in [the site’s] acacia plantings and has been recorded in forested areas as well...seems to be frequently found near human settlements...seen walking across the main road near the Samarakan nursery” (Belden et al., 2007: 36–37). This comes from an area where forest had been cleared only within the previous decade: the species inhabiting it at time of survey might include some unable to persist there into the long term. Also in Sarawak, JJH (pers. obs.) considers that short-tailed mongoose often wander into gardens and backyards of villages and comes into conflict with people; accounts from villagers about its devouring livestock and eggs are often heard. In many instances, it is captured and killed, sometimes eaten.

There seems to be no evidence of extensive use of the interior of oil palm plantation, with the limited information available suggesting that they are unlikely to be able to support the

Table 1. Summary of the occurrence records for short-tailed mongoose *Herpestes brachyurus* 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	115	18	36	114
Category 2 500 m – 2 km	23	10	14	12
Category 3 2–5 km	71	25	36	19
Category 4 above 5 km	20	–	–	3
Category 5 (no coordinates*)	32	–	–	3
Total	261	53	86	151

M₁ = Balanced Model; M₂ = Spatial Filtering Model (10 km); *only coarse location description was available.

Table 2. Land-cover reclassification for short-tailed mongoose *Herpestes brachyurus* based on questionnaire results of 13 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.69	3–4
Upland forest	2.91	1–4
Lower montane forest	2.10	1–4
Upper montane forest	0.89	0–2
Forest mosaics/lowland forest	2.79	*
Forest mosaics/upland forest	2.48	#
Swamp forest	1.80	0–4
Mangrove	0.90	0–3
Old plantations	2.11	0–3
Young plantations and crops	1.20	0–3
Burnt forest area	0.80	0–3
Mixed crops	1.30	0–3
Bare area	0.30	0–1
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).

species. In two oil palm plantations in Sabah, it was found in one but not the other; in forest contiguous with the latter it was found only very rarely (Sepilok Forest Reserve), forestalling conclusion about its response to oil palm per se. In the former, it was found in plantation only close to the plantation–forest boundary (JR and AJH pers. obs.). In an oil palm plantation in Central Kalimantan, Silmi et al. (2013) did not camera-trap the species in 608 camera-trap nights, but did not comment on whether it occurred in native forest in this region. In central Sumatra, it was not recorded in two oil palm plantations by Jennings et al. (2015) although it is not stated whether it inhabited native forest in the same region. Also in Sumatra, Maddox et al. (2007) did not find the species in oil palm plantations despite 25 camera-trap

records from forest in the same landscape and high survey effort in the oil palm, indicating at least at this site that oil palm stands are avoided. And in peninsular Malaysia, AM (pers. obs. 2012) did not camera-trap it in a survey of an oil palm–forest reserve landscape. Also in West Malaysia, Jennings et al. (2010) found all five radio-tracked animals to occur almost entirely within forest, a result which might, however, have been pre-ordained by trapping locations relative to habitat layout. The main study grid lay entirely within forest and at least 750 m from any plantation (see Jennings et al., 2010: Figs 1–2). Land at such distance was barely included in any of the tracked animals' home ranges in any direction even though to the north-east, north, west and south-west it was part of an extensive block of native

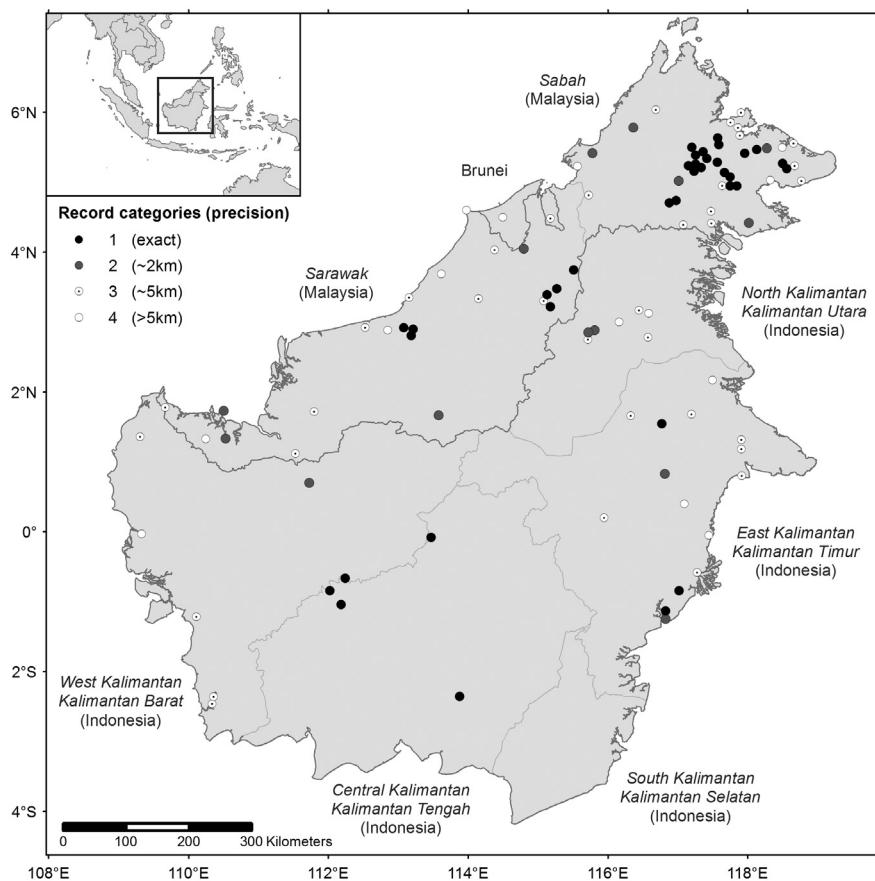


Fig. 2. Location of short-tailed mongoose *Herpestes brachyurus* occurrence records on Borneo, showing categories of spatial precision as well as country and state boundaries.

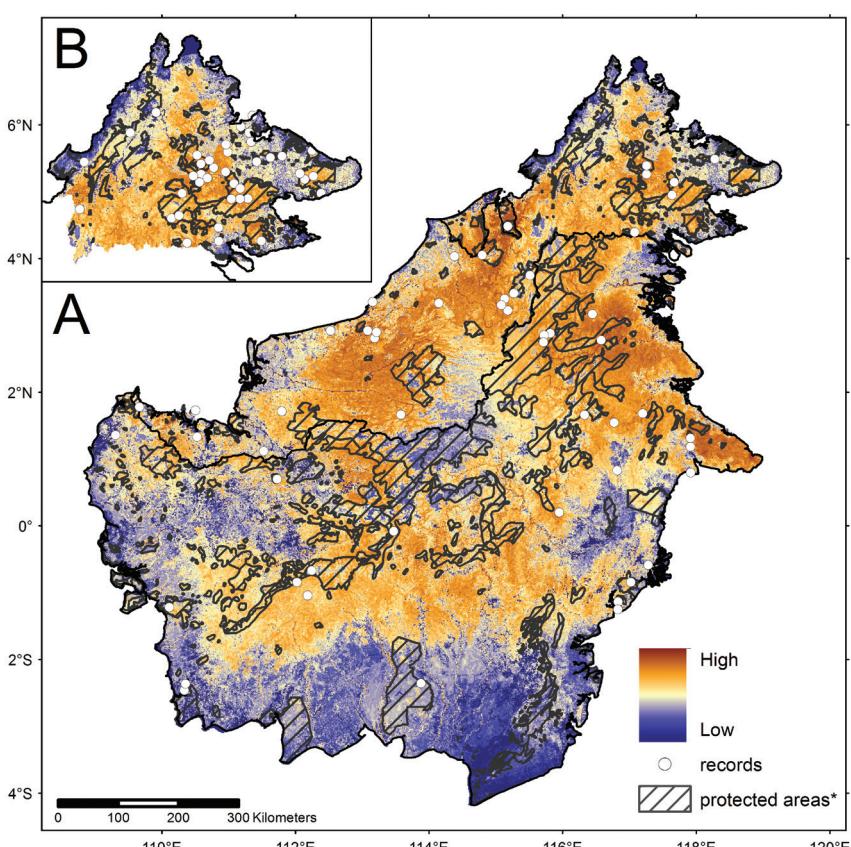


Fig. 3. Predictive Habitat Suitability Index (HSI) models for short-tailed mongoose *Herpestes brachyurus* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et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

forest. Thus, the plantation might simply have been too distant for regular use. The sole animal tracked into the plantation used small remnant forest patches and vegetated drainage ditches (Jennings et al., 2010), not stands of the plantation species itself. Levels of use of plantations of species other than oil palm remain even less clear.

All short-tailed mongoose records in West Malaysia known to Wells (1989) were from extreme lowland forest. Jennings & Veron (2011) collated records from across the species's range. They (p. 320) stated that "Short-tailed mongooses occur primarily in evergreen forest (81.7% [of records]) but also are found in plantations (8.5%), degraded forest (6.1%), and evergreen scrub (2.4%)...). Although they have been recorded up to 1,500 m [a.s.l.], short-tailed mongooses are mainly found at elevations between 0 and 600 m (97.6% [of records])". However, the proposal of a strong lowland forest association range-wide (including Borneo) is inappropriate. Jennings & Veron's (2011) implied assumption of a close relationship between the pattern of records and the species's distribution makes no allowance that purported patterns of occurrence might reflect wholly or partly search-effort heterogeneity. Dramatic heterogeneity is likely: of 6468 South-east Asian biodiversity research papers published between 1990 and 2010, Peh et al. (2011) found that 74% concerned lowland forest, whilst montane forest was covered in only 5% of papers. Even though contributors of small carnivore records in that part of South-east Asia occupied by short-tailed mongoose will not have spent their observation time according exactly to the proportionate breakdown of papers reviewed by Peh et al. (2011), a large concentration of records in the lowlands could plausibly arise from patterns of survey effort even if the species's population density was uniform with altitude.

The short-tailed mongoose records in Table 1 from Borneo also show a high concentration from below 600 m a.s.l. (90%), but with no meaningful ability to correct for differential survey effort across altitude, how this relates to the species's real distribution is unknown: the large bias of research effort towards lowland forest for South-east Asia as a whole (Peh et al., 2011) presumably encompasses Borneo. Historical records of the species in Borneo come from up to 3000' (915 m) a.s.l. on Gunung [=Mount] Dulit, Sarawak (Hose, 1893), up to 3900' (1190 m) a.s.l. on the Kelabit plateau, Sarawak (Davis, 1958), and up to 1500 m a.s.l. in the upper Sungai [=River] Padas, Sabah (Payne et al., 1985). The records in Table 1 include post-2000 ones from over 900 m from four well-separated highland regions. The two highest recent records from Borneo traced (too recent for inclusion in Table 1 and Fig. 2) come from Paya Maga, Sarawak, at 1548 m a.s.l., and from the Crocker Range, Sabah, at 1452 m a.s.l.; in both cases they were at the upper limit of the survey's camera-trapping (JJH pers. obs.; JR and AJH pers. obs.). These submontane records, being from multiple massifs, indicate that occurrence at such altitudes is not atypical in Borneo. Subjectively allowing for survey effort patterns, in Sabah the species seems to be less frequently recorded in the extreme lowlands than in the hills and mountains, but this remains to be confirmed (JR and AJH pers. obs.).

In West Malaysia, Wells (1989: 89) found that all precisely located records came from "100 m elevation or less, in primary or regenerating evergreen lowland forest". This profile was implicitly endorsed by Hedges et al. (2013), and was corroborated – with extension to 160 m a.s.l. – in Krau Wildlife Reserve by Jennings et al. (2010). This is in striking contrast to the number of Bornean massifs with records of the species not just above 160 m a.s.l. but above 900 m a.s.l. The apparent difference in altitudinal distribution between Borneo and West Malaysia parallels these land-masses' populations' deep genetic divergence (see above).

Habitat suitability index (HSI) model. The predictive habitat suitability map (Fig. 3) shows a low suitability across most of the plains of the southern half of Borneo, but the various locality records insufficiently precise to have been used by the model suggest that it might occur in a greater part of this area than a *prima facie* look at Fig. 3 would suggest. Nonetheless, it remains possible that while the species is certainly widespread (i.e., has a large extent of occurrence, *sensu* IUCN, 2012) in Borneo it might be rather localised and/or at low density in the island's southern half. Another area predicted to be of very low suitability is centred on the hilly tri-border of East and West Kalimantan with Sarawak. Its predictive unsuitability contrasts with the general prediction of such topography (for example the Sarawak–Kalimantan borderlands around 3–4°N) as suitable, reflective of records within 900–1500 a.s.l. in multiple areas of Sabah and Sarawak (see above). Whether the East–West Kalimantan–Sarawak tri-border is truly unsuitable or merely predicted to be so from a chance lack of records is unclear.

Another recent map modelling the species's range (Jennings & Veron, 2011: Fig. 2) gave generally similar results to Fig. 3; a large overlap in records used in both studies is likely. Both assessed the coastal lowlands as widely not suitable (plausibly reflecting widespread deforestation rather than inherent unsuitability). Both have much of the rugged hill terrain as somewhat to highly suitable, but indicate land above about 1800 m a.s.l. as largely unsuitable. One clear difference is in the treatment of South Kalimantan. Jennings & Veron (2011) predicted its main mountain range to be highly suitable, whereas Fig. 3 considers this chain little more suitable than the highly unsuitable adjacent lowlands. This is likely to reflect the strong focus of the present model (Fig. 3) on climatic variables (Kramer-Schadt et al., 2016) and the distinct dry season of this part of Borneo (see below), whereas Jennings & Veron (2011) used no climatic variables, only elevation and land-cover; thus this hill range was not discriminated from those known to be occupied elsewhere in Borneo. Which map has given a more realistic picture of range in this part of the island could be determined only by field survey. The other strong difference between the maps is that Jennings & Veron (2011) predicted West Kalimantan to be even less suitable than did the present model (Fig. 3), the difference extending into south-west Sarawak. This also might well reflect the strong influence of climate in the latter's model and its lack of direct incorporation in the former. An element of changing land-cover is also likely to contribute: Jennings & Veron's (2011) land-cover information

was generated from 1998–2000 satellite images, whereas the present model (Fig. 3) used information from 2007. In the interim, substantial additional areas might have been cleared (with the process continuing from 2007 to date).

The predictive habitat suitability map (Fig. 3) shows moderate overlap between the protected area system and predicted short-tailed mongoose range, consistent with the location of many protected areas in forest, the habitat hosting most research, and thus in which records are generated and for which there is some confidence that it is widely occupied in Borneo – at least in the island north of 2°N. Thus, the proposal of priority areas for the species seems unnecessary.

Brunei Darussalam. Brunei is predicted to be mostly highly suitable. Only two records from Brunei were traced, a paucity plausibly reflecting low survey effort, not scarcity of the species.

Sarawak, Malaysia. Most of Sarawak is predicted to be highly suitable or suitable, reflecting the many records, particularly from the northern half of the state. Highly suitable areas include most of the coastal lowlands away from the far west, perhaps a consequence of the concentration of records from the Sarawak Planted Forests, Bintulu, where the species is common (Belden et al., 2007). The areas of the state predicted to be less suitable may reflect the lack of consensus over the species's occupation of swamp forest, plantation and upper montane forests.

Sabah, Malaysia. Most of Sabah is predicted to be highly suitable, and there are many records. The immediate coastal fringe away from protected areas is mostly predicted to be unsuitable by the 'Balanced Model for the island of Borneo' (Fig. 3B). On the 'Spatial Filtering Model for Sabah' (Fig. 3A), with more records from Sabah, including its coastal fringe, much of this 'unsuitable' area is considered suitable, even highly suitable. Most of these areas have been converted to palm oil plantations and because of the lack of consensus about the suitability of plantations for this species, the additional records changed the model predictions.

North Kalimantan, Indonesia. Most of North Kalimantan is predicted to be highly suitable, even most of its south-western lobe from which no records were modelled; this presumably reflects general similarity in conditions to nearby areas with records.

East Kalimantan, Indonesia. Much of East Kalimantan is predicted to be highly suitable, and there are many records, particularly from the east and centre of the province. As with Sarawak and Sabah, the validity of the assessments of areas as of low suitability should be taken cautiously, given the uncertainty over the species's habitat use in Borneo.

South Kalimantan, Indonesia. South Kalimantan forms a large proportion of the largest block of land predicted as highly unsuitable for short-tailed mongoose. The model included no record from within about 100 km of it, and this area of the island has a harsher dry season than the rest of

Borneo, even though parts of East Kalimantan have lower total annual rainfall (extracted from Hijmans et al., 2005, 2015). The model's high weighting of climatic data means that it is unlikely to predict a species's occurrence within South Kalimantan if it has not yet been recorded. However, this area is also particularly under-surveyed relative to the rest of the island. Thus, it is premature to assert whether the lack of records from the area reflects a genuine absence or the low levels of survey there. A genuine absence is possible: unlike some other primarily Sundaic species of mammal, the known range of short-tailed mongoose does not extend up the Thai–Malay peninsula into the region with a significant dry season (Woodruff & Turner, 2009; Chutipong et al., 2014), indicating a potential tight restriction of short-tailed mongoose to areas with only a benign dry season.

Central Kalimantan, Indonesia. Central Kalimantan shows a large interior hill area predicted to be highly to fairly suitable for short-tailed mongoose versus the extensive coastal and interior lowlands that are predicted mostly to be less suitable, in some parts highly unsuitable. This pattern might reflect the real distribution of the animal, survey heterogeneity, or some combination of the two. With only five locality records, it is difficult to assess the relative roles of these factors. All five records are recent and located precisely: three in one area on the province's west border (Schwaner mountains; Samejima & Semiadi, 2012); one a little further north, also along the border (and in protected forest; T. van Berkel in litt., 2011); and one, more than 250 km from any other record traced, in the province's south-eastern lowlands (Sabangau Peat-swamp Forest; Cheyne et al., 2010). This is in a region predicted to be unsuitable: evidently its location is so divergent in modelled parameters from others that it has negligible effect on the model's prediction of suitability for the species. There are no imprecise records from the province, impairing discussion on whether the model predicts low suitability through genuine unsuitability or from a lack of records from climatically similar areas reflecting low search effort.

West Kalimantan, Indonesia. Most of West Kalimantan is predicted to be unsuitable or at best marginally suitable for short-tailed mongoose. However, this might well be misleading: five of the six records traced were insufficiently precise for use in the model. The deforestation of large areas of West Kalimantan is also likely to have predisposed the model against considering it suitable.

THREATS AND CONSERVATION PRIORITIES

The full set of conservation priorities for short-tailed mongoose on Borneo are unclear. Few locality records were traced from Borneo south of 2°N even though there are many in Sabah, northern Sarawak and North and East Kalimantan; the roles of uneven search effort and of a genuinely patchy occurrence in producing this pattern are unclear. Another notable finding is the uneven consistency of respondents' land-cover suitability scores. Together, these indicate a species still poorly known in Borneo. An obvious conservation-related priority at present is for better

information regarding distribution, habitat use (particularly of heavily encroached areas) and other aspects of ecology. As well as positive (presence) information, the interpretation of potential negative records (surveys not finding the species even though they were comparable in type and intensity of methods to those finding the species elsewhere) could help clarify distribution and habitat use on the island. Assuming that past statements that the species is a habitual climber are in error (see above), negative results of camera-trapping might be particularly useful, given that in some surveys the species is camera-trapped frequently (e.g., Ross et al., 2012).

Any locality records generated that lie more than 100 km from records in Fig. 2 warrant explicit publication: this includes much of West, Central and South Kalimantan. Also important are habitat-use studies (including radio-tracking) of the species in Borneo, particularly in landscapes well supplied with non-forest habitats. Information – positive or negative – concerning the use of habitats which the respondents scored highly inconsistently for suitability – upper montane forest, swamp forest, mangrove, plantations (of any age) and other crops (of any type), and burnt forest areas – is important to generate and publish, particularly where these concern at least one of regular presence; breeding; occurrence far (in home range terms – 1 km or so) from forest below 1200 m a.s.l.; and occurrence within areas deforested 20 or more years previously. Areas with reports of livestock conflict would be excellent choices for radio-tracking and other studies, as well as for assessing whether retaliatory killing has any population-level effect above the most local levels. Habitat-use information for short-tailed mongoose should be related specifically to particular land-mass (i.e., not by grouping together all or any of Borneo, Sumatra and the Thai–Malay peninsula).

Bird surveyors and leisure birdwatchers have added greatly to the available information on various diurnal small carnivores in South-east Asia (e.g., Duckworth et al., 2006; Supparatvikorn et al., 2012; and, although not explicit there, Abramov et al., 2008; Chutipong et al., 2014), particularly in habitats other than lowland evergreen forest. They could be a useful source of records for short-tailed mongoose, helping clarify distribution within southern Borneo and habitat use outside evergreen forest, provided adequate care is taken in screening for misidentifications.

Nothing suggests that short-tailed mongoose would be under any particular threat on Borneo. It has a large extent of occurrence on the island, and although there are large gaps between records in Borneo's southern two-thirds, this pattern might merely reflect survey effort. Although many records come from the Bornean lowlands, where forest has been extensively cleared, it occurs on the island (if not elsewhere in its range) to sufficiently high altitude to have a large range, and thus, presumably, populations, in forests not under high risk of near-term clearance (more than 97% of the deforestation in Borneo between 1973 and 2010 occurred in the coastal lowlands, below 500 m a.s.l.; Gaveau et al., 2015). No strong association is apparent with large wetlands (notwithstanding the sometime use of the name 'water-

mongoose' for it [Van Rompaey, 2000], which might refer to use of forest streams) or any other particularly threatened habitat feature. And although like all ground-dwelling small carnivores it is caught in non-selective traps, there is no evidence that it is subject to targeted hunting or that bycatch levels are high enough to cause widespread declines. Further information to allow a more confident judgement would be useful, although given the clear evidence that some other carnivores of Borneo are threatened, is not a conservation priority on the island.

Although not strictly relevant to Borneo, the species's status elsewhere is of much higher concern: clarification whether these other populations do comprise a species different from that on Borneo is urgent, and if they do, detailed collations (separately for Sumatra and West Malaysia) become equally urgent, to clarify habitat use (if it does not occur regularly above 200 m, its range overlaps highly with widespread landscape-level deforestation over the last few decades), current distribution and major threats.

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LITERATURE CITED

Abramov AV, Duckworth JW, Wang YX & Robertson SI (2008) The stripe-backed weasel *Mustela strigidorsa*: taxonomy, ecology, distribution and status. *Mammal Review*, 38: 247–266.

Azlan JM (2003) The diversity and conservation of mustelids, viverrids, and herpestids in a disturbed forest in peninsular Malaysia. *Small Carnivore Conservation*, 29: 8–9.

Belden G, Stuebing R & Nyegang M (2007) Small carnivores in mixed-use forest in Bintulu Division, Sarawak, Malaysia. *Small Carnivore Conservation*, 36: 35–37.

Bernard, H, Baking EL, Giordano AJ, Wearn OR & Abdul Hamid Ahmad (2014) Terrestrial mammal species richness and composition in three small forest patches within an oil palm landscape in Sabah, Malaysian Borneo. *Mammal Study*, 39: 141–154.

BirdLife International (2001) Threatened Birds of Asia: the BirdLife International Red Data Book. BirdLife International, Cambridge, U.K., 3038 pp.

Brodie J & Giordano A (2011) Small carnivores of the Maliau Basin, Sabah, Borneo, including a new locality for Hose's civet *Diplogale hosei*. *Small Carnivore Conservation*, 44: 1–6.

Cheyne SM, Husson SJ, Chadwick RJ & Macdonald DW (2010) Diversity and activity of small carnivores of the Sabangau Peat-swamp Forest, Indonesian Borneo. *Small Carnivore Conservation*, 43: 1–7.

Chutipong W et al. [23 authors] (2014) Current distribution and conservation status of small carnivores in Thailand: a baseline review. *Small Carnivore Conservation*, 51: 96–136.

Corbet GB & Hill JE (1992) The Mammals of the Indomalayan Region: a Systematic Review. Natural History Museum Publications and Oxford University Press, Oxford, U.K., 488 pp.

Davies G & Payne J (1982) A Faunal Survey of Sabah. World Wildlife Fund Malaysia (IUCN/WWF project n° 1692), Kuala Lumpur, Malaysia, 279 pp.

Davis DD (1958) Mammals of the Kelabit plateau, northern Sarawak. *Fieldiana, Zoology*, 39: 119–147.

Duckworth JW, Lee BPYH, Meijaard E & Meiri S (2006) The Malay weasel *Mustela nudipes*: distribution, natural history and a global conservation status review. *Small Carnivore Conservation*, 34&35: 2–21.

Gaveau DLA, Sloan S, Moliedena E, Yaen H, Sheil D, Abram NK, Ancrenaz M, Nasi R, Quinones M, Wielaard N & Meijaard E (2014) Four decades of forest persistence, clearance and logging on Borneo. *PLoS One*, 9(7): e101654.

Gilchrist JS, Jennings AP, Veron G & Cavallini P (2009) Family Herpestidae (mongooses). In: Wilson DE & Mittermeier RA (eds.) *Handbook of the Mammals of the World. Volume 1. Carnivores*. Lynx Edicions, Barcelona, Spain. Pp. 262–328.

Heaney LR (1986) Biogeography of mammals in SE Asia: estimates of rates of colonization, extinction and speciation. *Biological Journal of the Linnean Society*, 28: 127–165.

Hedges L, Clements GR, Aziz SA, Yap W, Laurance S, Goosem M & Laurance WF (2013) Small carnivore records from a threatened habitat linkage in Terengganu, peninsular Malaysia. *Small Carnivore Conservation*, 49: 9–14.

Hijmans RJ, Cameron SE, Parra JL, Jones PG & Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, 25: 1965–1978.

Hijmans RJ, Cameron S, Parra J, Jones P, Jarvis A & Richardson K (2015) WorldClim - Global Climate Data. Free Climate Data for Ecological Modeling and GIS. <http://www.worldclim.org/bioclim> (Accessed 25 May 2015).

Holden J & Meijaard E (2012) An orange-coloured collared mongoose *Herpestes semitorquatus* from Aceh, Sumatra, Indonesia. *Small Carnivore Conservation*, 47: 26–29.

Hose C (1893) A descriptive account of the mammals of Borneo. E Abbott, Diss, Norfolk, U.K., 78 pp.

IUCN (2012) *IUCN Red List Categories and Criteria. Version 3.1. Second edition*. IUCN, Gland, Switzerland and Cambridge, U.K., 32 pp.

IUCN (2015) The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org (Accessed 22 August 2015).

Jennings AP & Veron G (2011) Predicted distributions and ecological niches of 8 civet and mongoose species in Southeast Asia. *Journal of Mammalogy*, 92: 316–327.

Jennings AP, Akbar Zubaid & Veron G (2010) Home ranges, movements and activity of the short-tailed mongoose (*Herpestes brachyurus*) on peninsular Malaysia. *Mammalia*, 74: 43–50.

Jennings AP, Mohd Naim, Advento AD, Anak Agung Ketut Aryawan, Sudharto Ps, Caliman J-P, Verwilghen A & Veron G (2015) Diversity and occupancy of small carnivores within oil palm plantations in central Sumatra, Indonesia. *Mammal Research*, 60: 181–188.

Kramer-Schadt S, Reinfelder V, Niedballa J, Lindenborn J, Stillfried M, Heckmann I & Wilting A (2016) The Borneo Carnivore Database and the application of predictive distribution modelling. *Raffles Bulletin of Zoology*, Supplement 33: 18–41.

Low CHS (2011) Observations of civets, linsangs, mongooses and non-lutrine mustelids from peninsular Malaysia. *Small Carnivore Conservation*, 45: 8–13.

Maddox T, Priatna D, Gemita E & Salampessy A (2007) The Conservation of Tigers and Other Wildlife in Oil Palm Plantations. *Zoological Society of London (Conservation Report 7)*, London, U.K., 62 pp.

Mathai J, Hon J, Juat N, Peter A & Gumar M (2010) Small carnivores in a logging concession in the Upper Baram, Sarawak, Borneo. *Small Carnivore Conservation*, 42: 1–9.

Matsubayashi H, Lagan P, Majalap N, Tangan J, Abd Sukor JM & Kitayama K (2007) Importance of natural licks for the mammals in Bornean inland tropical rainforests. *Ecological Research*, 22: 742–748.

Matsubayashi H, Bernard H & Ahmad AH (2011) Small carnivores of the Imbak Canyon, Sabah, Malaysia, Borneo, including a new locality for the Hose's civet *Diplogale hosei*. *Small Carnivore Conservation*, 45: 18–22.

Payne J, Francis CM & Phillipps K (1985) *A Field Guide to the Mammals of Borneo*. The Sabah Society with World Wildlife Fund Malaysia, Kota Kinabalu and Kuala Lumpur, Malaysia, 332 pp.

Peh KS-H, Soh MCK, Sodhi NS, Laurance WF, Ong DJ & Clements R (2011) Up in the clouds: is sustainable use of tropical montane cloud forests possible in Malaysia? *Bioscience*, 61: 27–38.

Ross J, Gemita E, Hearn AJ & Macdonald DW (2012) The occurrence of reddish-orange mongooses *Herpestes* in the Greater Sundas and the potential for their field confusion with Malay weasel *Mustela nudipes*. *Small Carnivore Conservation*, 46: 8–11.

Ross J, Hearn AJ & Macdonald DW (in press) Lessons from an unknown guild: from ferret badger to otter civet in the Bornean carnivore community. In: Macdonald DW, Newman C & Harrington LA (eds.) *Biology and Conservation of Wild Musteloids*. Oxford University Press, Oxford, U.K.

Samejima H & Semiadi G (2012) First record of Hose's civet *Diplogale hosei* from Indonesia, and records of other carnivores in the Schwaner mountains, Central Kalimantan, Indonesia. *Small Carnivore Conservation*, 46: 1–7.

Schreiber A, Wirth R, Riffel M & Van Rompaey H (1989) Weasels, civets, mongooses, and their relatives. An action plan for the conservation of mustelids and viverrids. IUCN, Gland, Switzerland, 100 pp.

Schwarz E (1947) Colour mutants of the Malay short-tailed mongoose, *Herpestes brachyurus* Gray. *Proceedings of the Zoological Society of London*, 117: 79–80.

Silmi, M, Mislan, Anggara S & Dahlen B (2013) Using leopard cats (*Prionailurus bengalensis*) as biological pest control of rats in a palm oil plantation. *Journal of Indonesian Natural History*, 1(1): 31–36.

Supparatvirkorn S, Sutasha K, Sirisumpun T, Kunthawong N, Chutipong W & Duckworth JW (2012) Discovery of the yellow-bellied weasel *Mustela kathiah* in Thailand. *Natural History Bulletin of the Siam Society*, 58: 19–30.

Van Rompaey H (2000) The short-tailed mongoose, *Herpestes brachyurus*. *Small Carnivore Conservation*, 23: 17–21.

Veron G, Patou ML, Debruyne R, Couloux A, Fernandez DAP, Wong ST, Fuchs J & Jennings AP (2015) Systematics of the Southeast Asian mongooses (Herpestidae, Carnivora) – solving the mystery of the elusive collared mongoose and Palawan mongoose. *Zoological Journal of the Linnean Society*, 173: 236–248.

Wahyudi D & Stuebing R (2013) Camera trapping as a conservation tool in a mixed-use landscape in East Kalimantan. *Journal of Indonesian Natural History*, 1(2): 37–46.

Wells DR (1989) Notes on the distribution and taxonomy of peninsular Malaysian mongooses. *Natural History Bulletin of the Siam Society*, 37: 87–97.

Wilson DE, Helgen KM, Chin Sing Yun & Belden G (2006) Small mammal survey at two sites in planted forest zone, Bintulu, Sarawak. *Malayan Nature Journal*, 59: 165–187.

Wilting A, Samejima H & Mohamed A (2010) Diversity of Bornean viverrids and other small carnivores in Deramakot Forest Reserve, Sabah, Malaysia. *Small Carnivore Conservation*, 42: 10–13.

Wilting A, Duckworth JW, Belant JL, Duplaix N & Breitenmoser-Würsten C (2016) Introduction: distribution of and conservation priorities for Bornean small carnivores and cats. *Raffles Bulletin of Zoology*, Supplement 33: 1–8.

Woodruff DS & Turner LM (2009) The Indochinese–Sundaic zoogeographic transition: a description and analysis of terrestrial mammal species distributions. *Journal of Biogeography*, 36: 803–821.

Wozencraft WC (1993) Order Carnivora. In: Wilson DE & Reeder DM (eds.) *Mammalian Species of the World. A Taxonomic and Geographic Reference*, 2nd Edition. Smithsonian Institution Press, Washington D.C. Pp. 279–348.