

Predicted distribution of banded linsang *Prionodon linsang* (Mammalia: Carnivora: Prionodontidae) on Borneo

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

Abstract. Banded linsang *Prionodon linsang* is restricted to Sundaic South-east Asia and inhabits a wide altitudinal range. It occurs widely in Borneo, including all political units except perhaps South Kalimantan, with many recent records. It has never been studied in the field. Usually, it is recorded only once or a few times on any given camera-trap or spotlighting survey within its range. Only rarely is it among the most commonly found small carnivores. It probably occurs at lower densities than do many small carnivores and conventional survey methods are probably suboptimal at finding it. Its popular reputation for rarity and thus conservation priority has no compelling foundation and seems unlikely to be valid. It is not known or likely to be targeted by human hunters and it has been suggested to be associated with edge and degraded areas. Seventy spatially precise records were used to model its distribution. Habitat reclassification scores for use in the model showed wide variation across respondents: few people have seen banded linsang many times. It is tied to forest, including highly degraded and, perhaps, fragmented areas. The predicted suitable habitat map suggests large overlap between the protected area system and the species's range, and a large predicted area outside protected areas. Identification of priority areas for the species is thus impracticable. If population densities are typically low, banded linsang might need relatively large landscapes for long-term viability. Without understanding this, and the extent, if any, to which it uses plantation landscapes, it is difficult to speculate how well protected areas and other mechanisms to retain native forest on Borneo will secure representative populations of this species. Another uncertainty important to resolve is the difficulty of interpreting the species's status through camera-trapping.

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

Abstrak (Bahasa Indonesia). Linsang *Prionodon linsang* hanya terdapat pada Dataran Sunda-Asia Tenggara dan menyebar pada daerah yang tinggi. Dari beberapa catatan terakhir kehadirannya, jenis ini menyebar luas di Pulau Borneo, di seluruh batas administrasi kecuali Kalimantan Selatan. Jenis ini secara khusus belum pernah diteliti di lapangan. Sebenarnya, tercatat kehadirannya hanya sesekali atau beberapa kali dengan menggunakan kamera trap atau beberapa catatan temuan di daerah sebarannya. Merupakan jenis yang jarang ditemukan di antara jenis karnivora kecil yang umum. Kemungkinan hal ini terjadi karena kepadatan jenis ini rendah dibandingkan karnivora kecil yang lain, dan metoda survey yang digunakan adalah metoda konvensional sehingga tidak optimal menemukan jenis ini. Oleh karena itu untuk kelangkaan dan prioritas konservasinya tidak dapat dijadikan dasar karena tidak diketahui atau sepertinya merupakan satwa target bagi pemburu dan tampaknya jenis ini juga berasosiasi dengan daerah tepi hutan dan kawasan terdegradasi. Tujuh puluh catatan spasial yang tepat telah digunakan untuk pemodelan sebaran. Skoring reklasifikasi habitat yang digunakan pada modeling menunjukkan variasi yang berbeda antar responden, yang juga mencerminkan bahwa ada beberapa orang yang telah menemukan jenis ini berkali-kali. Hal ini terkait juga dengan kawasan hutan, termasuk yang sangat terdegradasi dan mungkin kawasan yang terfragmentasi. Peta prediksi kesesuaian habitat menunjukkan overlapping antara kawasan lindung dengan sebaran habitat, tetapi sebagian besar habitat berada di luar kawasan lindung sehingga hasil identifikasi kawasan prioritas tampak berlebihan. Jika kepadatan populasi rendah, dalam jangka panjang Linsang mungkin memerlukan landscape yang relative luas untuk kelestariannya. Tanpa pemahaman yang jelas dan sejauh ini, sebagian landscape digunakan untuk perkebunan, sehingga sulit berspekulasi bagaimana melindungi kawasan lindung secara baik dan membuat mekanisme lain untuk mempertahankan hutan asli Borneo yang akan mengamankan populasi jenis ini. Hal lain yang juga penting untuk menambah pemahaman namun juga tidak pasti adalah kesulitan menafsirkan status jenis ini melalui studi kamera trap.

Abstrak (Bahasa Malaysia). Linsang *Prionodon linsang* terhad taburannya di Kepulauan Sunda Asia Tenggara dan menghuni jurang ketinggian yang lebar. Di Borneo, ia tersebar secara meluas di mana terdapatnya rekod terkini, termasuk kesemua daerah politik kecuali Kalimantan Selatan. Ia tidak pernah dikaji di lapangan. Kebiasannya, di mana ia dijumpai, ia direkodkan hanya sekali atau beberapa kali sahaja dalam kajian menggunakan perangkap kamera atau suluhan lampu. Di antara karnivor berbadan kecil yang lain, spesis ini jarang ditemui, kerana berkemungkinan mempunyai densiti taburan yang lebih rendah dan kaedah kajian konvensional mungkin tidak memadai untuk menemukan spesis ini. Reputasinya sebagai spesis yang jarang sebagai alasan kepentingan pemuliharaannya tidak mempunyai asas yang kukuh, kerana tidak diketahui tetapi berkemungkinan bahawa spesis ini menjadi

sasaran pemburu dan juga dikaitkan dengan habitat pinggiran dan terjejas. Skor untuk klasifikasi habitat daripada responden melihatkan jurang yang lebar, menunjukkan spesis ini hanya ditemui dengan kerap oleh segelintir orang sahaja. Ia dikaitkan dengan hutan malar hijau (termasuk kawasan terjejas teruk dan kemungkinan juga kawasan berfragmentasi) tetapi kesesuaian relatif untuk kelas-kelas hutan tidak diketahui dengan jelas. Peta jangkaan habitat yang sesuai menunjukkan pertindihan yang luas di antara sistem kawasan terlindung dengan jangkaan spesis ini, dan jangkaan habitat yang luas di luar kawasan terlindung menjadikan identifikasi kawasan perlindungan penting tidak diperlukan. Sekiranya kepadatan populasi adalah rendah, Linsang mungkin memerlukan landskap yang lebih luas untuk kemandirian jangka panjang. Tanpa memahami ini, dan setakat mana ia menggunakan kawasan ladang, amat sukar untuk meramalkan sejauh mana kawasan terlindung dan mekanisme lain untuk mengekalkan hutan asli di Borneo akan menjamin populasi spesis ini. Satu lagi ketidakpastian yang harus ditangani ialah kesukaran menginterpretasi status spesis ini melalui perangkap kamera.

INTRODUCTION

Asian linsangs *Prionodon* Horsfield, occur widely in the Greater Sundas, mainland South-east Asia, southern China and north-east India. They comprise two clearly distinct species, banded linsang *P. linsang* (Hardwicke), in the Sundaic part of the range (Borneo, Java, Sumatra [including also Bangka and Belitung], peninsular Malaysia, southern Thailand and southern Myanmar) and spotted linsang *P. pardicolor* Hodgson, to the north (e.g., Van Rompaey, 1993, 1995; Chutipong et al., 2014; Jennings & Veron, 2015). This genus has never been studied in the field. It is known only from records during general collecting expeditions and surveys, observation of captive animals, and study of museum material (e.g., Van Rompaey, 1993, 1995). Asian linsangs are rarely amongst the small carnivores most commonly recorded during a survey, regardless of technique used, although there are exceptions (see below). More usually, banded linsang (Fig. 1) is camera-trapped, spotlighted by night or live-trapped once or a few times on any given survey within its range (e.g., Heydon & Bulloh, 1996; Azlan, 2003; Holden, 2006; Steinmetz & Simcharoen, 2006; Than Zaw et al., 2008; Cheyne et al., 2010; Mathai et al., 2010; Wilting et al., 2010; Brodie & Giordano, 2011; Low, 2011; Chutipong et al., 2014). Whether this generally low recording rate represents genuinely low population density, elusive behaviour, or a combination of the two, is not clear (Van Rompaey, 1993). The genus has a popular reputation for rarity and, thus, needing conservation attention, but there is no good evidence for this. At least for spotted linsang, recent records indicate a high adaptability to habitat degradation and fragmentation, and to hunting (e.g., Lau et al., 2010; Duckworth, in press). Banded linsang is strongly nocturnal (Van Rompaey, 1993). Although certainly an excellent climber, and often said to be highly arboreal, trapping locations and gut contents indicate that it spends much time on the ground (Van Rompaey, 1993); subsequent camera-trapping corroborates this. This does not necessarily mean that it would be readily camera-



Fig. 1. Banded linsang *Prionodon linsang* camera-trapped in Crocker Range Park, Sabah, Malaysia, on 26 December 2011. (© Andrew Hearn/WildCRU)

trapped: several species of ground-dwelling South-east Asian weasel *Mustela* Linnaeus, are camera-trapped only rarely, even where known by other methods to be present (Duckworth et al., 2006; Abramov et al., 2008; Ross et al., 2013; Chutipong et al., 2014). Many behavioural and microhabitat characters can affect the chance of a species being camera-trapped, in addition to its abundance. Perhaps the author with the most direct knowledge of banded linsang in the wild, Lim (1973), considered it frequently to inhabit secondary and edge tangles. These are not typical camera-trapping areas. Nothing is known about its home-range sizes or population densities.

Banded linsang is categorised as Least Concern on The IUCN Red List of Threatened Species (IUCN, 2015). This designation is based on limited information and is strongly dependent upon Lim (1973) and other qualitative assessments that the species inhabits edge, degraded and secondary forests. There is no suggestion that population declines (which are presumably occurring, at least in proportion of conversion of forest into non-forest habitats) are severe enough to warrant another category, and it is much too numerous and widespread to trigger any range or population size criterion even for Near Threatened. The species is legally protected in Sarawak and Sabah (Malaysia) and in Indonesia, but not in Brunei

RESULTS AND DISCUSSION

Species occurrence records. In total, 112 records were collated; 25 were excluded from modelling because their spatial precision was too low (over 5 km; Categories 4 and

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Table 1. Summary of the occurrence records for banded linsang *Prionodon linsang* 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	42	19	34	42
Category 2 500 m – 2 km	12	3	8	2
Category 3 2–5 km	33	16	28	9
Category 4 above 5 km	20	–	–	4
Category 5 (no coordinates*)	5	–	–	0
Total	112	38	70	57

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

Table 2. Land-cover reclassification for banded linsang *Prionodon linsang* based on 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	3.40	3–4
Lower montane forest	2.80	1–4
Upper montane forest	2.20	0–4
Forest mosaics/lowland forest	2.29	*
Forest mosaics/upland forest	2.26	#
Swamp forest	2.50	1–4
Mangrove	1.40	0–3
Old plantations	1.50	0–3
Young plantations and crops	0.80	0–2
Burnt forest area	0.40	0–2
Mixed crops	1.00	0–2
Bare area	0.00	0–0
Water and fishponds	0.17	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).

5), whereas 42 records had high precision (under 2 km, Category 1) and were collected within 2001–2011 (Table 1). Most records were collected from Sabah, but records were obtained from all Borneo's political units (Fig. 2). Because of search-effort bias, only 38 (Balanced Model = M₁) or 70 (Spatial Filtering Model = M₂) were used for modelling (see Kramer-Schadt et al. (2016) for methods).

Habitat associations. Perhaps no surveyor or researcher has seen unrestrained banded linsangs many times. Unsurprisingly, the habitat reclassification scores showed wide variation across the eight respondents of the questionnaire (Table 2), with three of the 15 categories being scored from 0 or 1 to 4, and two more from 0 to 3. The only strongly consistent

responses were for lowland forest and upland forest (highly suitable, and where most camera-trapping occurs, meaning respondents would be best informed) and bare areas, water and fishponds, and water (unsuitable). Other highly-ranked habitats, on average, comprised lower and upper montane forest, and swamp forest. Other low-ranked habitats, on average, comprised mangrove, old plantations, young plantations and crops, burnt forest area, and mixed crops. In some habitats camera-trapping is particularly challenging through risk of flooding, e.g., mangroves and swamp forest. Unsurprisingly, these habitats had individual assessments ranging from 0 to 3 and 1 to 4 respectively. Less expected was the wide range of scores for old plantations and for lower and upper montane forest, suggesting a dearth of camera-

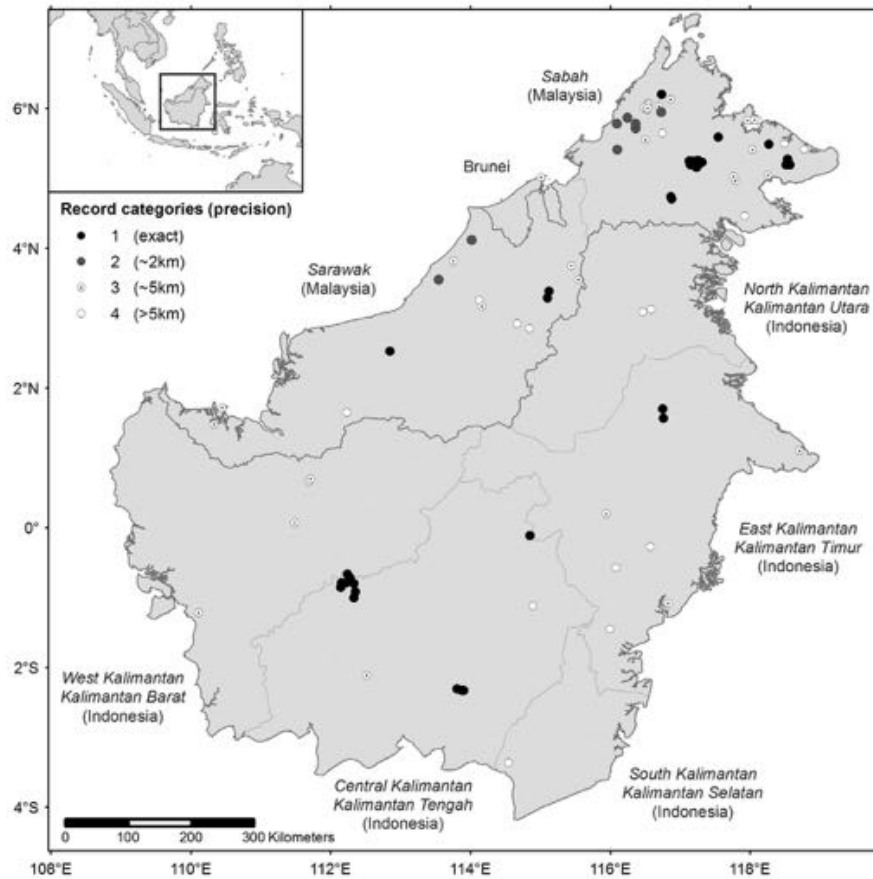


Fig. 2. Location of banded linsang *Prionodon linsang* occurrence records in Borneo, showing categories of spatial precision as well as country and state boundaries.

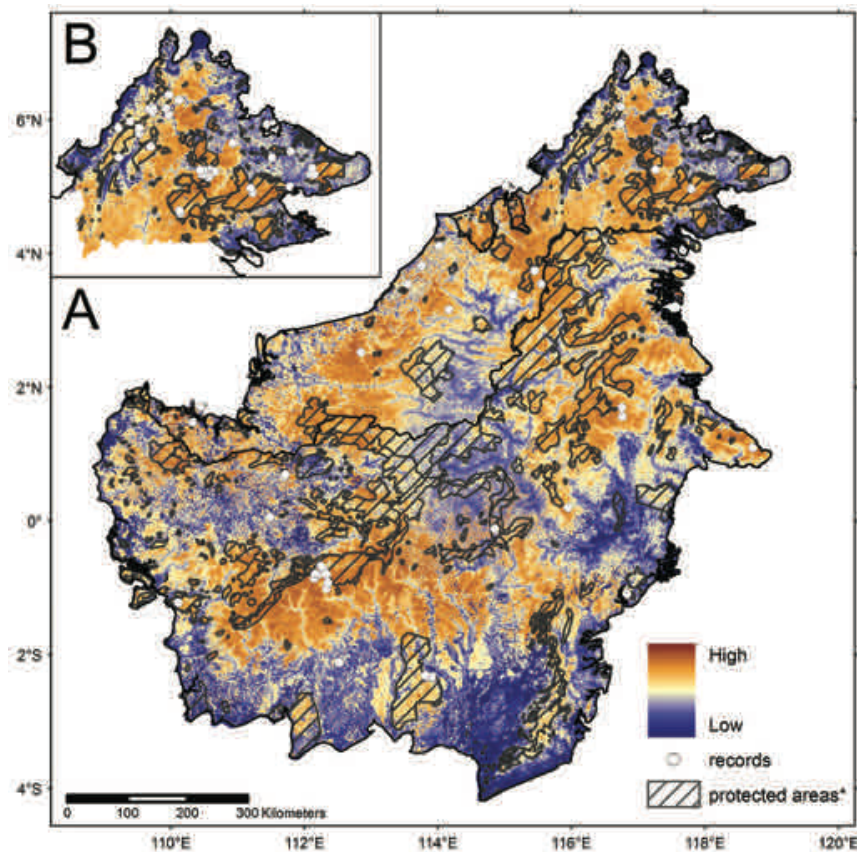


Fig. 3. Predictive Habitat Suitability Index (HSI) models for banded linsang *Prionodon linsang* including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al. (2016).

trapping programmes (or at least of wide knowledge of their results) sustained in these habitats long enough to inform on the status of a species typically recorded only infrequently. It is clear that banded linsang uses montane forest: Payne et al. (1985) traced Bornean records from as high as 1800 m a.s.l., while AJH et al. (pers. obs.) found it regularly, and at multiple camera-trap stations, on Crocker Range, Sabah, over 1300 m (up to 1421 m, within 30 m of the upper limit of their camera-trapping). Globally, Jennings & Veron (2015) knew of records from up to 2700 m a.s.l. and considered that the species has no clear altitudinal preference. It has been recorded in peat swamp forest (Cheyne et al., 2010), but whether it occurs regularly there and, if it does, whether populations isolated in such habitats can survive in the long term, are unknown. The low consensus, overall, on habitat reclassifications for this species might have resulted in an average picture not faithfully representing banded linsang's habitat use in Borneo.

Habitat suitability index (HSI) model. The predicted suitable habitat map (Fig. 3) suggests large overlap between the protected area system and predicted banded linsang range. This is consistent with the location of many protected areas in typical forest, the habitat in which most spotlighting occurs, and thus where records are generated and for which there is high confidence that it is widely occupied. But there is also a large predicted range outside protected areas. Indeed, more than for most other species of Bornean small carnivore, wide occurrence in relatively degraded areas is predicted (cf. other species papers in this issue). Therefore identification of priority areas for the species seems not to be practicable, and probably superfluous.

Another recent map modelling the species's range (Jennings & Veron, 2015: Fig. 2) gave broadly similar results to the present model (Fig. 3); a large overlap in records used in both studies is likely. In both, the coastal lowlands are mostly predicted to be not currently suitable, plausibly reflecting widespread deforestation rather than inherent unsuitability. Both have much of the rugged hill terrain as somewhat to highly suitable. The main difference between the maps is that Jennings & Veron (2015) predicted central Borneo to be uniformly highly suitable whereas the present model (Fig. 3) predicts a large, somewhat dendritic area around the East Kalimantan–Central Kalimantan–Sarawak tri-border area to be unsuitable. This might reflect the strong influence of climate in the latter's model and its lack of direct incorporation in the former, which used only altitude and land-cover. Only direct survey in this area could indicate which model gives a more realistic picture there.

Brunei Darussalam. Brunei is predicted to be almost entirely highly suitable. This reflects the predominant natural vegetation cover of lowland and hill dipterocarp forest, and so far a lower proportion of conversion to monoculture plantations and other non-forest uses than in much of the rest of Borneo. The paucity of Brunei records presumably reflects low survey effort there.

Sarawak, Malaysia. Much of Sarawak is predicted to be highly suitable, reflecting the predominant natural vegetation cover of lowland and hill dipterocarp forest, albeit now mostly logged over. The areas predicted to be less suitable for the species are mostly extensive oil-palm landscapes such as around Bintulu and the Rejang delta.

Sabah, Malaysia. Much of Sabah is predicted to be highly suitable, where natural vegetation cover of lowland and hill dipterocarp forest survives. The extensive oil palm plantations in the eastern and northern part of the state are predicted to be of low suitability, but only further survey in these plantations, including in the small forest patches within them, could test this prediction.

North Kalimantan, Indonesia. Most of North Kalimantan is predicted to be highly suitable. As with Malaysian Borneo this reflects the predominant natural vegetation cover of lowland and hill dipterocarp forest.

East Kalimantan, Indonesia. Much of East Kalimantan is predicted to be highly suitable, reflecting the extensive hill dipterocarp forest and lower montane forest in the western uplands in particular. A large area of the centre-east, inland from Samarinda, is predicted to be highly unsuitable; its heavy deforestation is compounded by repeated large fires.

South Kalimantan, Indonesia. Most of South Kalimantan outside the Meratus highlands is predicted to be highly unsuitable. This area of Borneo has the harshest dry season, although parts of East Kalimantan have lower total annual rainfall (extracted from Hijmans et al., 2005, 2015). Banded linsang records at the northern extent of its world range, in Thailand, suggest an association with true evergreen forest rather than the semi-evergreen forests predominant in this region (Steinmetz & Simcharoen, 2006), and a localised distribution in South Kalimantan would be consistent with this. The predictive map suggests that in South Kalimantan, banded linsang is most likely to occur in the mountains; here, seasonal dryness is likely to be ameliorated. However, this area is among the least surveyed parts of Borneo, so the species might in fact occur across a wide altitudinal range there, but not so far have been well recorded, with the mountains coming up as more suitable simply because they are more similar in climate to the areas where the species has been recorded. The single record obtained from South Kalimantan is imprecisely located and its location, Banjarmasin (Van Rompaey, 1993) is a trading port. It is therefore possible that this specimen had been procured elsewhere.

Central Kalimantan, Indonesia. Central Kalimantan shows a large interior hill area predicted to be highly to fairly suitable for banded linsang versus most of the extensive coastal and interior lowlands that are predicted to be moderately or highly unsuitable. Surprisingly, much of the north and east interior is also predicted to be unsuitable. This could reflect the real distribution of the animal, survey heterogeneity, or some combination of the two. The distribution of the several imprecisely located records (not used in the model) suggests

that banded linsang might yet be found to be widespread within the predicted low suitability area. The concentration of records in one area on the province's west border (Schwaner mountains: see below) might result from high survey effort using techniques appropriate for the species there, but similar techniques were used by the same team in Sabah where they found the species only occasionally. This suggests that the Schwaner mountains might genuinely be particularly suitable for the species.

West Kalimantan, Indonesia. West Kalimantan is predicted to be mostly somewhat unsuitable or at best marginally suitable for banded linsang. West Kalimantan is not overall well surveyed, so whilst only four records of banded linsang were traced from the province this does not necessarily indicate genuine rarity of the species there.

THREATS AND CONSERVATION PRIORITIES

It is unclear whether there are any conservation priorities for banded linsang on Borneo, beyond extensive retention of native forest. Its extent of occurrence encompasses almost the entire island, the many localities indicate the likelihood of a large area of occupancy, it inhabits a wide altitudinal range, and most records come from hill forest, a widespread habitat. It is therefore unlikely to have a localised distribution. Many records come from over 500 m a.s.l., and thus above the zone of heavy deforestation (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., 2014). There is no evidence of targeted or heavy hunting from anywhere in its world range. There seems to be no information concerning its susceptibility to intense trapping, which, assuming it does spend significant time on the ground, might pose a threat (although, as noted above, spotted linsang is evidently able to survive heavy such pressures).

As a forest species, banded linsang persistence in Borneo is likely therefore to depend on the retention of native forest, both as effectively managed protected areas and as carefully run selective logging areas. The possibility that population densities are typically low (but see below) suggests that banded linsang might need relatively large landscapes for long-term viability. Linked to this, it would be useful to establish the extent, if any, to which it can use extensive plantations of the types now covering much of Borneo (oil palm, rubber and acacia). Without understanding these issues, it is difficult to speculate the proportion of protected areas and other mechanisms that retain native forest (whether or not logged) on Borneo that will retain populations of this species.

Another uncertainty important to resolve is the difficulty of interpreting the species's status through camera-trapping. It is difficult yet to tell whether the typically low camera-trap encounter rate reflects a genuinely low typical density of the animals, a suboptimal technique as typically applied, or some combination of the two. In Deramakot Forest

Reserve, Sabah, Wilting et al. (2010) did not record banded linsang in their main camera-trap survey area, although they photographed it concurrently six times elsewhere in the reserve. While the difference in linsang encounter rate might simply be locational, it might plausibly be methodological (see Sollmann et al., 2013): the main survey area's camera-traps were set along active or abandoned logging roads, but the others were set randomly within the forest. This latter style, by some of the same personnel, generated Samejima & Semiadi's (2012) remarkably high recording rate in the Schwaner mountains. They found the species widely in the surveyed area, and the overall high rate did not result from many repeat encounters at one or a few camera-trap stations. This suggests that camera-traps set within forest are more likely to detect banded linsang than are those along roads. But the encounter rate in Deramakot was much lower than that in the Schwaner mountains: perhaps the latter comprise particularly suitable banded linsang habitat. High heterogeneity in camera-trap encounter rate even with similar style (a standard trail/ridge focus for camera-trap stations) across survey areas was found in the Sabah surveys of AJH et al. (own data). These recorded banded linsang on 53 occasions at 19 (of 33) camera-trap stations in the Crocker Range, an encounter rate and proportion of camera-trap stations far exceeding those on similar surveys elsewhere in Sabah (for locations, see Ross et al., 2013). However, it would be premature to conclude that the differences in encounter rate across these uniform Sabah surveys necessarily reflect those in population density: as a speculative potential alternative, linsangs climb well, but not, apparently, generally very high; and if they prefer to move within the vegetation column than along the ground, then differences in the contiguity of the shrub layer could have large effects on the encounter rate by ground-level camera-traps. There are also a few cases from outside Borneo where banded linsang is among the most frequently camera-trapped small carnivores, from Java (Yoneda et al., 1998) and from West Malaysia (Hedges et al., 2013).

In sum, as long as the uncertainties remain of how camera-trapping style, local vegetation structure and possibly other factors affect encounter rate, the precise status of this animal will continue to be elusive.

Perhaps the most effective investigation would use radio-tracking with frequent visual location of the animals, to clarify microhabitat use and nightly movement patterns, two factors which strongly affect camera-trap encounter rates. In a world of finite resources for conservation, and with several other Bornean carnivores clearly or probably at high risk of extinction, the urgency for this is lower than for researching the conservation-related unknown aspects of the various other Bornean species under clear threat: nothing indicates that banded linsang is declining beyond the rate of forest conversion and that general biodiversity conservation initiatives (which are often shaped around species with large area needs) will not cater for it incidentally.

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